# Canada–New Brunswick–Nova Scotia New Finfish Aquaculture Species Development Program Summary Report 1995-2000

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# Canada–New Brunswick–Nova Scotia New Finfish Aquaculture Species Development Program

## Summary Report 1995-2000

by

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The Canada–New Brunswick–Nova Scotia New Finfish Aquaculture Species Development Program was funded primarily by the Cooperation Agreement on Economic Diversification between Canada and New Brunswick and the similar agreement between Canada and Nova Scotia. Most of the projects received additional funding from other sources, including the Atlantic Canada Opportunities Agency, the National Research Council's Industrial Research Assistance Program, the Natural Sciences and Engineering Research Council, and the various host agencies. The information presented in this report was taken from annual project reports, research proposals, conference and workshop presentations, and scientific publications reporting research supported by the Program. R. Henry, D. Saunders, and B. Bradford provided annual reports for the individual projects. R. Peterson provided information on striped bass and eel culture projects in the Maritimes. Various Steering Committee members provided comments on drafts of this report. The research priorities for 2000-2005 for halibut, haddock, small flounders, and sturgeon were taken from the draft Aquaculture Research and Development Strategy 2000-2005, developed by the New Brunswick Department of Agriculture, Fisheries and Aquaculture (August 2000).

## EXECUTIVE SUMMARY

A 5-year research and development program was conducted, from 1995-2000, to promote aquaculture of new finfish species in the Maritime Provinces. The Canada-New Brunswick-Nova Scotia New Finfish Aquaculture Species Development Program received funding of approximately $1 million per year from the Cooperation Agreement on Economic Diversification between Canada and New Brunswick (approximately 75%) and the similar agreement between Canada and Nova Scotia (25%).

The Program was led by the New Brunswick Department of Fisheries and Aquaculture (now part of the Department of Agriculture, Fisheries and Aquaculture) and Fisheries and Oceans Canada, Maritimes Region. Other major partners included the Atlantic Canada Opportunities Agency, the Nova Scotia Department of Fisheries and Aquaculture, the National Research Council's Institute for Marine Biosciences, university researchers, and the aquaculture industry.

Priority species were selected, based on biological and economic criteria. The highest priority species were halibut, haddock, and winter flounder. Limited funding was also provided for striped bass and American eel research. American eel research was discontinued after 1997-98. Sturgeon (shortnose and Atlantic species) was added to the priority species list in 1998.

By the end of the Program, two juvenile halibut hatchery facilities (Maritime Mariculture Inc. and R&R Finfish Development Ltd.) were operating, with a total production of about 50,000 weaned juveniles in 1999 and in 2000. High mortality rates in early stages continued to occur, but survival rates generally improved. Malpigmentation problems were overcome. Growout trials were initiated in modified salmon cages and tanks.

Juvenile haddock were also being produced at two hatcheries (New Brunswick Department of Fisheries and Aquaculture's Aquarium and Marine Centre in Shippagan and National Research Council's Institute for Marine Biosciences), with production of over 60,000 weaned juveniles in 1999 and more than 100,000 in 2000. However, high mortality rates between hatching and weaning and during weaning continued to occur. Juveniles produced by the hatcheries were transferred to sea cages at a salmon growout site of Connors Bros. Ltd. on Deer Island, for growout trials in modified salmon cages.

Winter flounder was initially thought to be already close to commercialization, based on promising research results prior to the start of this Program. However, juvenile mortality problems were experienced and one of the initial partners (Sambro Fisheries Ltd.) decided not to proceed with winter flounder culture. A new small flounder hatchery program was initiated at the Huntsman Marine Science Centre in 1999-2000 and some growout trials were started.

Striped bass was considered to have limited culture potential because the Maritimes is the northern limit of the range of this species. However, there was some industry interest in this species, so some research was supported. Use of black tanks and a short photoperiod was found to improve the larval swimbladder inflation rate, which is a major factor affecting larval survival and growth. Other work looked at optimal diets and environmental conditions for larval and juvenile rearing. At least one company in Nova Scotia is producing small numbers of cultured striped bass.

American eel was also considered to have limited culture potential but, because of industry interest, some research was supported. An experiment examining the possible role of winter temperature on sex determination produced negative results. Research was completed on dietary requirements and diet development for juveniles. One company continues to culture eels in New Brunswick, and other companies have indicated interest.

Sturgeon research was supported starting in 1999-2000, following the initiation of sturgeon culture by two New Brunswick companies, Supreme Sturgeon and Caviar Ltd. and the Canadian Caviar Co. Shortnose sturgeon culture would be primarily for caviar production, while Atlantic sturgeon may be better suited for meat production. Research was conducted on feeding regimes, optimal temperatures, and optimal densities for growth. Considerable mortalities were encountered, due to disease and operational problems. However, progress was made on determining optimal conditions (feeding strategies, temperatures, and densities) for early stages and growout. Since sturgeon grow best at higher temperatures, it appears that heated recirculation systems will be required. Mature fish (for caviar) have not yet been produced for either species.

Nutrition research included work on dietary requirements, feeding regimes, and feed development for the different life stages of the priority species. However, more research is still required on the nutritional requirements and diet development for all species. One important need is for the development of artificial diets to replace the requirement for live feeds for the larval stages.

The main role of the fish health component was the diagnosis of health problems at the various culture facilities. Bacterial loading appeared to be responsible for many of the mortality problems encountered. A new, rapid DNA profiling technique was developed for bacterial profiling of samples from hatcheries. Work was conducted on ways of reducing the bacterial loading.

While considerable progress was made on the culture of the various priority species, especially halibut and haddock, additional research is required before any of these species reaches the commercialization stage. A new 5-year program has been proposed to build on the positive research outcomes achieved during the 1995-2000 program.

Progress and results from the research and development projects were communicated at workshops sponsored by the Program, at scientific conferences, as well as in scientific and technical publications.

## SOMMAIRE

De 1995 à 2000, un programme de recherche-développement a été exécuté afin de promouvoir l'élevage de nouvelles espèces de poisson dans les provinces Maritimes. Cette initiative, connue sous le nom de *Programme Canada – Nouveau-Brunswick –Nouvelle-Écosse de mise en valeur de la culture de nouvelles espèces de poisson*, a pu être réalisée grâce à une aide financière d'environ 1 million de dollars par an qui a été octroyée dans le cadre de deux ententes de coopération sur le développement économique, la première entre le Canada et le Nouveau-Brunswick (environ 75 % de l'aide financière) et la seconde entre le Canada et la Nouvelle-Écosse (25 % du total).

On a d'abord procédé à la sélection des espèces prioritaires en fonction de critères biologiques et économiques. Les espèces retenues pour les études étaient le flétan, l'aiglefin et la plie rouge. Des sommes moins importantes ont aussi été accordées pour l'étude du bar rayé et de l'anguille. Les recherches sur l'anguille ont cependant été interrompues après l'exercice 1997-1998. L'esturgeon (esturgeon à museau court et esturgeon noir) a été ajouté à la liste des espèces prioritaires en 1998.

À l'expiration du programme, deux écloseries de flétans juvéniles (la Maritime Mariculture Inc. et la R&R Finfish Development Ltd.) étaient en exploitation, la production totale se chiffrant à quelque 50 000 juvéniles sevrés en 1999 et en 2000. Toutes deux ont enregistré des taux de mortalité élevés au cours des premières étapes du cycle biologique, mais le taux de survie s'est progressivement amélioré. Après avoir surmonté les problèmes causés par les défauts de pigmentation, les deux installations ont engraissé les flétans dans des cages et des bassins à saumon modifiés.

Du côté des aiglefins, l'élevage des juvéniles était également pratiqué par deux écloseries (le Centre marin et aquarium du ministère des Pêches et de l'Aquaculture du Nouveau-Brunswick, à Shippagan, et l'Institut des biosciences marines du Conseil national de recherches). En 1999, la production se chiffrait à plus de 60 000 juvéniles sevrés, tandis que, en 2000, elle était passée à plus de 100 000 individus. Malgré tout, le taux de mortalité demeure élevé entre l'éclosion et le sevrage, tout comme pendant l'étape du sevrage proprement dite. Les aiglefins juvéniles produits par ces écloseries ont été transférés aux installations de grossissement du saumon de Connors Bros. Ltd., à l'île Deer, pour l'engraissement expérimental dans des cages à saumon modifiées.

Les recherches menées avant le début du programme laissaient croire que l'élevage commercial de la plie rouge était presque déjà une réalité. Toutefois, les écloseries ont connu des problèmes de mortalité juvénile, et l'un des partenaires initiaux (la société Sambro Fisheries Ltd.) a abandonné le projet. Malgré tout, le Centre des sciences de la mer Huntsman a aménagé une petite écloserie de plie rouge en 1999-2000 et a procédé à certains essais de grossissement.

Le bar rayé était considéré comme une espèce à faible potentiel aquacole, parce que les provinces Maritimes se trouvent à la limite nord de son aire de distribution. L'espèce suscitait néanmoins un certain intérêt au sein de l'industrie, si bien que des fonds ont été accordés pour la conduite d'études. Les chercheurs ont découvert que le recours à des bassins noirs et une diminution de la photopériode favorisaient le gonflage de la vessie natatoire chez les larves, facteur qui influe grandement sur le taux de survie et de croissance des larves. Ils ont également effectué des recherches sur les conditions environnementales et les régimes alimentaires optimaux pour l'élevage des larves et des juvéniles. À l'heure actuelle, le bar rayé est élevé à petite échelle dans au moins une installation aquacole de la Nouvelle-Écosse.

L'anguille semblait elle aussi présenter un faible potentiel aquacole, mais, par suite de l'intérêt manifesté par l'industrie, certaines études ont été financées dans le cadre du programme. Une expérience visant à examiner le rôle possible de la température hivernale sur la détermination du sexe a produit des résultats

négatifs. D'autres recherches ont été menées sur les besoins nutritionnels et le développement d'aliments pour les juvéniles. Une entreprise poursuit actuellement l'élevage de l'anguille au Nouveau-Brunswick, et d'autres ont manifesté de l'intérêt à cet égard.

Des études sur l'esturgeon ont été financées en 1999-2000, après que deux sociétés du Nouveau-Brunswick, la Supreme Sturgeon and Caviar Ltd. et la Canadian Caviar Co., aient entrepris l'élevage de cette espèce. Les deux entreprises entendaient cultiver l'esturgeon à museau court principalement pour la production du caviar et l'esturgeon noir pour la chair. Des recherches ont été menées sur les régimes d'alimentation, les températures optimales et la densité optimale pour la croissance. La mortalité était élevée, en raison de maladies et de problèmes liés aux installations. Malgré tout, les chercheurs sont parvenus à déterminer les conditions optimales (régimes d'alimentation, températures et densité) pour les premières étapes du cycle biologique et pour le grossissement. Comme l'esturgeon se développe mieux dans des eaux chaudes, il faudra vraisemblablement se doter de systèmes de recirculation chauffés pour l'élevage de cette espèce. Les écloseries n'ont pas encore produit d'esturgeons matures (des deux espèces) pour le caviar.

En ce qui a trait à la nutrition, les scientifiques se sont surtout penchés sur les besoins nutritionnels, les régimes d'alimentation et les formules d'aliments requises pour chaque étape du cycle biologique des espèces prioritaires. Il reste encore cependant beaucoup de recherche à faire sur les besoins nutritionnels et le développement d'aliments. Il importera notamment de produire des aliments artificiels pour remplacer les proies vivantes qui servent de nourriture aux larves.

En ce qui a trait à la santé des poissons, les chercheurs se sont employés à diagnostiquer les problèmes de santé observés dans les diverses installations aquacoles. La charge bactérienne semble avoir été la cause d'un grand nombre des problèmes de mortalité. Les chercheurs ont mis au point une technique des empreintes génétiques pour l'analyse bactérienne rapide des échantillons provenant des écloseries. De plus, ils ont effectué des travaux sur les moyens de réduire la charge bactérienne.

Bien que des progrès importants aient été accomplis, surtout chez le flétan et l'aiglefin, il faudra d'autres études avant de pouvoir envisager de faire l'élevage commercial de ces espèces prioritaires. Un nouveau programme quinquennal a maintenant été proposé afin de poursuivre les recherches prometteuses amorcées dans le cadre du programme de 1995-2000.

Les progrès accomplis et les résultats des initiatives de recherche-développement ont été communiqués au cours d'ateliers parrainés par les responsables du programme et lors de conférences scientifiques, ainsi que dans des publications scientifiques et techniques.

# INTRODUCTION

The Canada–New Brunswick–Nova Scotia New Finfish Aquaculture Species Development Program was a 5-year, comprehensive research and development program aimed at accelerating the commercialization of key new finfish aquaculture species in Atlantic Canada. The development partners were a unique blend of industry, federal and provincial agencies, and research institutions in New Brunswick and Nova Scotia. The impetus for the Program was a joint recognition that the aquaculture industry in these provinces was overly dependent upon salmon farming and that, consequently, there was a need to diversify the industry in order to minimize the potential impacts of depressed prices or disease problems in farmed salmon. The research program began in 1995 and continued until 2000. During the last year of the Program, plans were being made for a new 5-year program, which would build on the considerable progress made up to 2000.

## *Background*

Aquaculture, primarily that of Atlantic salmon, was the most rapidly growing aspect of the agri-business sector in Atlantic Canada in the 1980s and 1990s. In the Bay of Fundy, where the first cage culture of farmed salmon in Atlantic Canada was conducted in the late 1970s, the industry was worth about $100 million by 1994, and represented the primary source of income for several coastal communities. However, competition for North American markets from other salmon producing countries resulted in depressed prices, and production increased worldwide. Diversification of the aquaculture industry by increasing the number of species cultured is one way to stabilize the incomes of fish farmers. Unfortunately, for most other species of potential aquaculture value, the required culture technology has not been developed.

## *Organizational Structure*

The Province of New Brunswick proposed an aquaculture development program for non-traditional species (finfish and shellfish) in 1993. In the following year, funding was approved and steering committees were set up to coordinate separate finfish and shellfish programs (Cook and Watson-Wright 1995). These steering committees were sub-committees of the Canada–New Brunswick Memorandum of Understanding on Aquaculture Development.

The steering committee of the New Finfish Aquaculture Species Development Program first met in late 1994. The main roles of the steering committee were: to review and recommend research and development priorities for each candidate species; to review and recommend action plans for each species; and to monitor and evaluate the progress of these action plans.

The steering committee was initially co-chaired by Mr. David MacMinn, Assistant Deputy Minister of the New Brunswick Department of Fisheries and Aquaculture (NBDFA) and Dr. Wendy Watson-Wright, Director of the St. Andrews Biological Station of Fisheries and Oceans Canada (DFO). Steering Committee co-chairs and members during the duration of the Program are listed in Appendix 3. The key partners in the Program were:

- New Brunswick Department of Fisheries and Aquaculture (NBDFA)[1]
- Fisheries and Oceans Canada (DFO)
- Nova Scotia Department of Fisheries and Aquaculture (NSDFA)[2]

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[1] In April 2000, this department became part of the New Brunswick Department of Agriculture, Fisheries and Aquaculture.

[2] In October 2000, this department became part of the Nova Scotia Department of Agriculture and Fisheries.

- Atlantic Canada Opportunities Agency (ACOA)
- National Research Council - Institute for Marine Biosciences (NRC-IMB)
- universities
- other R&D organizations
- the aquaculture industry

Subcommittees were formed to ensure that the workplans for each research and development component (see below) had clearly defined objectives and deliverables that were implemented in an effective and efficient manner. In addition, a Planning and Administration Subcommittee ensured that the Program was delivered in a cost-efficient manner. Appendix 4 lists the dates and locations of Steering Committee meetings held between 1994 and 2000.

Funding was provided by the Cooperation Agreement on Economic Diversification between Canada and New Brunswick and the similar agreement between Canada and Nova Scotia. Total funding was approximately $1 million per year for 5 years, with about 75% from the New Brunswick agreement and 25% from the Nova Scotia agreement. Funding from this Program was intended to supplement funding provided by the proponents and/or from other sources such as the Atlantic Canada Opportunities Agency (ACOA), the National Research Council's Industrial Research Assistance Program (NRC-IRAP) and the Natural Sciences and Engineering Research Council (NSERC). Appendix 6 lists the major research and development partners in this Program. Appendix 7 lists the projects funded during each year of the Program.

### *Research and Development Components*

The Program had five research and development components and although identified separately for clarification, each was inherently linked with the other components. The five components were:

1) broodstock collection and management
2) rearing of early life stages
3) nutrition
4) fish health
5) engineering and technology

Summarized below are the general deliverables for the various components of the research and development program.

### I. Broodstock Collection and Management

Funds were used to capture broodstock or purchase them from commercial fishermen, for acquisition of adequate equipment (tanks, nets, air compressors) and to cover the costs of moving broodstock from the collection area to the holding sites. Sufficient numbers of broodstock halibut, haddock, striped bass, and winter flounder were required to ensure adequate genetic diversity for development of strains particularly suitable for aquaculture. Spatial segregation of broodstock fish among several sites in New Brunswick and Nova Scotia ensured against total loss of broodstock if problems were encountered at any one site.

Funds were required for food and general husbandry supplies for the sites holding broodstock. Additional funds were targeted to research and development activities in several critical areas: environmental influences on maturation, influence of diets on egg quality, methods to predict and control maturation state. Capital requirements included holding tanks, spawning tables,

environmental monitoring equipment, sea cage rental, and some analytical equipment such as an ultrasound scanner to assess gonadal development. Much of the remaining funds were used to employ staff for technical assistance in maintaining the broodstock.

**II. Early Rearing**

The objective of the early rearing component was to gain the knowledge to successfully rear the difficult early stages of the target species and generate a sufficient supply of juveniles to test ongrowing market potential and profitability of fish cultured through the entire life cycle. The early rearing component was the critical phase with considerable research and development required. Funds were required for facilities, equipment, and materials. Labor was required to maintain the rearing programs, as rearing of marine fish larvae is a labor-intensive operation.

**III. Nutrition**

The funding for the nutrition component was to be used to determine the nutritional requirements for culturing new finfish species and to develop techniques and feeds for meeting these requirements. Suggested topics included:

- Techniques for culturing native species of marine plankton for use as larval food organisms, plus knowledge of their nutritional composition;
- Techniques for producing nutritionally adequate and palatable micro-encapsulated larval diets; determination of nutritional requirements of juvenile stages; studies of larval feeding behavior, to provide information on food acceptance and optimal food particle sizes; and
- Evaluation of the performance (i.e. growth and survival) of juveniles with live food and dry food types.

**IV. Fish Health**

Funding for the fish health component was intended to assist in providing diagnostic services for the various research sites, as well as research required to identify and determine life histories of infectious diseases and parasites that cause problems in culturing the various life stages of these new culture species. The goal was to develop the diagnostic and treatment technology required to maintain these species in good health in captivity.

**V. Engineering and Technology Development**

The funding for this component went toward reviewing existing research facilities and determining requirements for culture of new finfish species. Consulting services were provided to deal with problems encountered at the various facilities. Another component was the development of bioeconomic models for the selected species.

***Priority Species***

The priority species were selected through consultations among provincial, federal, and industry representatives. They were selected on the basis of a combination of factors:

- High market prices for wild-caught fish and popularity with consumers;
- Declining or prohibited wild fisheries such that a niche should be available for the cultured product;
- The presence of wild stocks of the species in our waters (the introduction of exotic species was not considered desirable);

- Knowledge of the basic life history so that reasonable approaches to their culture could be designed; and
- Reasonably rapid growth to market size.

Indications of interest from industry partners and the availability of local research expertise were also important, as was the desire not to duplicate work being done elsewhere in Canada. The research being done on cod aquaculture in Newfoundland was an example of this latter concern. As a result, cod was not included in this Program.

The initial candidate species selected for this Program were:

| *Common name – English* | *Common name - French* | *Scientific name* { TC "8. List of species" \f C \l "1" } |
|---|---|---|
| (Atlantic) halibut | flétan (de l'Atlantique) | *Hippoglossus hippoglossus* |
| Haddock | églefin, aiglefin | *Melanogrammus aeglefinus* |
| Winter flounder | plie rouge | *Pseudopleuronectes americanus* |
| Striped bass | bar rayé, bar d'Amérique | *Morone saxatilis* |
| American eel | anguille américaine | *Anguilla rostrata* |

It was recognized that the latter two species had more limited market potentials in Atlantic Canada than the other species. However, some research on the culture potential of striped bass and eels in the Maritimes had already been done and there was some industry interest in growing these two species. For these reasons, it was decided to support some research on striped bass and eels, although at a lower level than for the other priority species.

It was also recognized that the list of priority species could change over the duration of the Program, as more information on these and other species was obtained. Eel research was discontinued after 1997-98. Sturgeon (shortnose and Atlantic species; esturgeon à museau court, esturgeon noir; *Acipenser brevirostrum, A. oxyrhynchus*) were added to the priority species list in 1998, following the initiation of sturgeon aquaculture research by two New Brunswick companies. Sturgeon aquaculture is of interest for caviar production and possibly also for meat production.

The priority species were selected to allow exploitation by a wider variety of techniques than are utilized for salmon: either through differences in salinity and temperature tolerances or through differences in life history traits. For example, eel and sturgeon culture require recirculation systems, while the flatfishes require new cage technologies or may be better suited to land-based, tank rearing systems. The development of aquaculture technologies for these species would therefore have relevance to all coastal communities throughout Atlantic Canada.

The Program sponsored five workshops between 1995 and 1999 (Appendix 5). These workshops served to update the Steering Committee members and the various research and development partners of the progress being made in each of the projects funded by the Program. In addition, research findings were communicated to a broader audience through scientific publications (Appendix 1) and presentations given at conferences (Appendix 2).

The following section provides an overview of the research sponsored by the New Finfish Aquaculture Species Development Program. The information presented was taken from progress reports and annual reports for individual projects, presentations given at conferences and workshops, and published reports.

# OVERVIEW OF RESEARCH AND DEVELOPMENT ACCOMPLISHMENTS

## HALIBUT (*Hippoglossus hippoglossus*)

### *Background*

Research on Atlantic halibut aquaculture began in Norway and Scotland in the early 1980s, with the first cultured juvenile production occurring in Norway in 1985 (Brown and Keough 1994). Research in the Maritimes began at DFO's St. Andrews Biological Station (SABS) in 1988, led by K. Waiwood (Waiwood et al. 1994, 1997). Initial research at SABS included broodstock collection and maintenance, rearing of early life stages, and growout trials using wild-caught juveniles in modified herring weirs, modified salmon net cages, and a bottom cage. The growout trials showed that halibut could grow considerably faster under culture conditions than in the wild. The first production of juvenile halibut in North America was at SABS in 1993, when 48 juveniles were produced (Waiwood et al. 1994).

An agreement between Maritime Mariculture Inc. (MMI) and DFO resulted in the construction of a pilot scale halibut hatchery at SABS in 1996. The agreement included the transfer of Norwegian technology on broodstock maintenance, reproduction, and juvenile production. The MMI hatchery produced its first juveniles in 1996. The hatchery was moved from SABS to the nearby Huntsman Marine Science Centre (HMSC) in 1998. Another halibut operation, R&R Finfish Development Ltd. (R&R), was established at East Ferry, Digby County, NS. Broodstock were held at this site starting in 1996 and a pilot scale juvenile halibut production facility was started in 1997. There is one other halibut facility in the Maritimes, Scotian Halibut Ltd., which began operations in 1997 at Clark's Harbour in southwestern Nova Scotia. This company has not requested funding from this Program, but has received loan assistance from Canadian and Nova Scotian government agencies.

### *Research supported by the New Finfish Aquaculture Species Development Program*

The Program supported broodstock collection, broodstock holding at various sites, broodstock spawning and reproduction research at SABS (D. Martin-Robichaud), juvenile production projects at MMI (led by D. Raymond; see Raymond 1998) and R&R (research led by N. Brown), nutrition research, and fish health diagnostics.

#### Broodstock

Halibut broodstock were held at various sites in New Brunswick and Nova Scotia. At the start of this Program, some broodstock were already being held at SABS, Harbour DeLoutre Products Ltd. (HDL) on Campobello Island, NB, and the NBDFA Aquarium and Marine Centre (AMC) in Shippagan. Using the DFO vessel *CCGS J.L. Hart*, additional broodstock were collected from the Bay of Fundy in the spring/summer of each year of the Program in a collaborative project involving NBDFA (St. George) and DFO (SABS). A total of about 75 halibut broodstock were collected or purchased and transported to broodstock facilities at SABS, HDL, and MMI (at HMSC). Also, cultured halibut from the 1993 production at SABS were first spawned in 2000. The approximate numbers of halibut broodstock being held in early 2000 are shown in the following table.

| *Broodstock facility* | *Approximate numbers of broodstock (early 2000)* |
|---|---|
| SABS (flow-through tanks) | 90 |
| HDL (sea cages) | 30 |
| AMC (recirculation tanks) | 17 |
| R&R (flow-through tanks) | 33 |
| MMI (at HMSC) (flow-through tanks) | 46 |

Funds were provided in 1995-96 to upgrade the SABS broodstock facility. The upgrades allowed photoperiod and temperature control of broodstock tanks, as well as degassing capabilities and other improvements. Funds were also provided each year for additional labor at SABS during the halibut spawning season.

SABS was the main supplier of eggs and sperm for the hatcheries and research projects that were supported by the Program. SABS broodstock were initially kept in ambient conditions, with egg production taking place from March till May. Starting in 1997, some fish were kept on advanced photothermal regimes, to allow earlier production of eggs. For the 2000 spawning season, SABS broodstock were maintained on 1 and 2 month advanced regimes, extending the spawning period to 5 months, with egg production beginning in February. R&R produced the first eggs from its broodstock (which were captured in 1996 and 1997) in 1999.

Egg fertilization rates have improved during the Program. Fertilization rates reported in 2000 were 80% at MMI and 67% at R&R. Research at SABS investigated how the temperature and salinity of the water used in fertilization affected the viability and fertilization rate of halibut eggs. Viability was unaffected by temperature (2-8°C) and salinity (27-36 ‰), but varied between egg batches. The effect of temperature on fertilization rate was statistically, but not practically significant, since the greatest difference in fertilization rates between temperatures was only 5%. There were no apparent effects of salinity on fertilization rates (Martin-Robichaud and Rommens 1998). Fatty acid analyses of 70 halibut egg samples at SABS (J. Castell, D. Martin-Robichaud) indicated some correlations between egg lipid composition and fertilization rates.

Research at SABS studied the short-term storage of halibut gametes. This is important because unfertilized gametes are transported from the spawning (broodstock) facilities to the hatcheries, where fertilization takes place. Fertilization rates attained using unfertilized eggs and milt stored for up to 64 h (at 1-3°C and 0-1°C, respectively) were 80-90% of controls (Martin-Robichaud and Rommens 2000).

A project at the National Research Council's Institute for Marine Biosciences (NRC-IMB), led by M. Reith, used microsatellite markers to determine the parentage and genetic background of juvenile halibut in culture facilities. This information can be used to identify successful crosses and to investigate the contributions of various parameters on juvenile survival.

SABS personnel developed ultrasound techniques to determine the sex of immature halibut and to monitor gonadal maturity (Martin-Robichaud et al. 1998a and 1998b). This tool is particularly useful for broodstock management.

A problem encountered with halibut culture is that under simulated natural photoperiod, spermiation commences about 1-2 months prior to ovulation. Research conducted at SABS found that gonadotropin-releasing hormone (GnRH) implants could be used to extend the production of good quality milt in spermiating males (Martin-Robichaud et al. 2001).

Related research (not directly funded by the Program) on the use of sex steroids to produce all-female halibut stocks (see Hendry et al. 2001) was conducted at SABS, in conjunction with the University of New Brunswick (UNB). Because females grow faster and mature later than males, all-female stocks would be advantageous for aquaculture.

**Larval and Juvenile Production**

The Program provided support to juvenile halibut production facilities at MMI starting in 1996-97 and at R&R starting in 1997-98. Both facilities used flow-through seawater systems. The tanks in use for various stages in 1999 were:

| *Stage* | *Tank types used at MMI and R&R in 1999* |
|---|---|
| Egg incubation (14-16 days duration) | 0.14-0.25 $m^3$ cylindroconical upwelling incubators (flow-through) (up to 450 eggs/L); temperature controlled at 5-6°C. |
| Yolk sac larvae (40-50 days duration) | 0.7-0.9 $m^3$ cylindroconical upwelling silos (flow-through) (20-40 larvae/L); temperature controlled at 5-7°C. |
| Feeding juveniles | 1-8 $m^3$ circular and square tanks (flow-through) (1-5 juveniles/L). |

Both facilities reported hatching rates (for viable eggs) averaging 50-70%, using eggs and sperm produced by SABS broodstock.

Estimated juvenile production at the two juvenile production facilities is shown in the following table.

| *Facility* | *Weaned juvenile halibut production per year-class (to October/November of first year - approx. 2-10 g)* | | | | |
|---|---|---|---|---|---|
| | *1996* | *1997* | *1998* | *1999* | *2000* |
| MMI | 11,000 | 2,600 | 15,000 | 7,000 | 25,000 |
| R&R | - | 1,850 | 8,000 | 43,000 | 30,000 |

MMI indicated that the target survival rate from hatched larvae to weaned juveniles is about 5%. Estimated survival rates obtained at MMI and R&R from 1995-1999 are shown in the following table.

| | *% Survival from hatched larvae to weaned juveniles (to October-November of first year) by year-class* | | | | |
|---|---|---|---|---|---|
| | *1996* | *1997* | *1998* | *1999* | *2000* |
| MMI | 1 | <1 | 3 | 1 | 4 |
| R&R | - | 3 | 3 | 10 | 8 |

The major obstacles encountered at MMI were poor survival of yolk sac larvae and low start-feeding success. Survival of yolk sac larvae (as a percentage of the number of hatched larvae) at MMI improved from 11% in 1996 to 22% in 1997, 28% in 1998, 35% in 1999, and 62% in 2000. In 1999, there was a high percentage of abnormal yolk sac larvae, especially "gapers" (abnormal jaw development). "Gapers" made up 36% of yolk sac larvae in 1999, compared to <10% in 1997 and 1998. These "gapers" were unable to feed, and therefore did not survive through start-feeding. The high percentage of abnormal yolk sac larvae in 1999 may have been related to high silt levels in the water supply that year.

Start-feeding success (as a percentage of the number of yolk sac larvae produced) at MMI was 8% in 1996, 1.4% in 1997, 18% in 1998, 4% in 1999, and about 9% in 2000. The poor start-feeding success in 1997 was attributed to high bacterial loading and insufficient live feed (from the wild zooplankton collection) during critical stages of start-feeding. The improved start-feeding success in 1998 occurred in the new MMI facility at HMSC, using new, smaller yolk sac silos and an improved wild zooplankton collection system. The poor start-feeding success in 1999 was attributed to the high percentage of abnormal yolk sac larvae produced that year. Another problem reported by MMI in 1998 and 1999 was that many larvae stopped feeding at around 35-40 days after transfer to start-feeding silos. This may have been due to bacterial loading (*Vibrio* sp.), since antibiotic treatments were sometimes able to reduce mortalities.

Weaning of juveniles to artificial diets was not considered to be a problem. Weaned juveniles (about 1 g) could be produced in about 100-150 days post-hatch. MMI reported that weaning success was usually about 80%. In 1998, MMI reported some mortalities after weaning. These mortalities were attributed to bacterial and viral pathogens, probably related to stress caused by gas supersaturation.

MMI implemented operational modifications to address the problems encountered. These included: increased water filtration (UV treatment), increased chilling capacity, vacuum degassing, oxygen injection, reduction in the use of wild zooplankton (to reduce introduction of parasites, toxins, bacteria), improved *Artemia* disinfection (use of *Hatch Control*™ disinfectant and freshwater rinsing), and improved laminar flow to the silos.

Juvenile production at R&R showed similar survival rates to MMI in 1997 and 1998, then improved markedly in 1999. In that year, R&R reported 79% yolk sac survival and 16% survival through start-feeding and metamorphosis.

A conceptual design for a flow-through, production-scale hatchery on the Bay of Fundy coast, New Brunswick was prepared for MMI by Fundy Engineering & Consulting Ltd. The report concluded that the direct use of heated wastewater from power plants was not a feasible source of heated water for this type of hatchery.

**Growout**

MMI started growout trials in May 1997, using 1996 year-class juveniles (about 8,300 juveniles, averaging 50 g each). These fish were placed in modified salmon cages at HDL (Campobello Island, NB). For halibut culture, salmon cages were modified to include a bottom frame and a tight cage bottom of fine mesh or tarpaulin. More than 50% mortalities occurred in the summer of 1997, apparently due to sunburn problems (ulcerative dermatitis as a primary infection and *Vibrio* sp. as a secondary infection). Shading was subsequently added to the cages to prevent sunburn. There were almost no mortalities over winter. The surviving juveniles averaged 600 g in October 1998 and 1.9 kg in November 1999.

MMI also kept 1997 year-class juveniles in flow-through tanks and a raceway at HMSC. These fish had reached an average weight of 900 g in November 1999. Juveniles from the 1998 year-class were transferred to sea cages at HDL in May-July 1999 at weights of 65-200 g.

The results obtained by MMI indicated that the most likely halibut culture scenario would require 8-10 months in land-based tanks (to 100-150 g), transfer of juveniles to sea cages in early summer of their second year, and about 3 years of growout in sea cages to market size (4-5 kg). However, MMI has also suggested that it may be possible to transfer juveniles to sea cages in sheltered locations in their first fall (at 10-20 g).

Juveniles produced by R&R in 1997 were grown at the East Ferry facility in flow-through tanks and raceways, including the use of shelving to allow higher densities. Growout trials of juveniles produced by R&R in 1997 and 1998 were also conducted in sea cages in the Annapolis Basin, NS and at Grand Manan Island, NB.

**Nutrition**

Broodstock were fed frozen fish, squid, and shrimp, as well as moist extruded feed, and vitamin supplements.

The MMI operation used a combination of wild zooplankton and enriched *Artemia* for first feeding of larvae. Norwegian experience showed that halibut larvae require high levels of specific fatty acids (predominantly docosahexaenoic acid, DHA) during the first few weeks of feeding, in order to attain normal pigmentation. These fatty acids are found naturally in wild zooplankton. MMI had malpigmentation problems in 1996, when only 55% of juveniles showed normal pigmentation. This was attributed to a shortage of wild zooplankton during the early start-feeding period in June of that year. From 1997-98 to 1999-2000, MMI reported over 98% normal pigmentation. The improvement was attributed to an improved wild zooplankton collection system. The R&R operation, using only enriched *Artemia* for first feeding, reported greater than 95% normal pigmentation of juveniles in 1999.

MMI conducted *Artemia* enrichment experiments, in collaboration with SABS. It was found that both exposure time and enrichment media strongly influenced the total lipid content and essential fatty acid composition of *Artemia* (Blair et al. 1998b).

An experiment conducted from November1998 to February 1999 at MMI compared the performance in tanks of post-weaning juvenile halibut (1998 year-class; initial average weights 3.0-3.3 g) fed on various commercial diets and an experimental diet developed by NRC-IMB (S. Lall). There were significant variations in growth among the diets. The experimental diet showed promising results, but caused some tank hygiene problems as it was an extremely soft pellet that broke down quickly.

R&R conducted feeding trials on post-weaning juveniles (1997 year-class; initial average weights 2-5 g) in tanks, starting in October 1997. Reported feed conversion ratios (FCRs) using pellets formulated for juvenile flatfish ranged from 0.61-0.73 (October 1997 to January 1998).

Research at SABS, in collaboration with MMI, indicated that juvenile halibut (initial average weight 13.6 g) have a relatively high protein requirement. Juveniles fed diets containing 60% protein had better growth, survival, and feed conversion rates than those fed diets with lower protein levels (test diets ranged from 40-60% protein). Lipid levels (ranging from 13-22%) had no significant effects on growth and survival (Blair et al. 1999).

Juvenile on-growing trials were conducted in tanks at R&R in July-December1997 using 1996 year-class fish from MMI (average initial weights 67-103 g). Fish fed a semi-moist feed performed better than those fed two commercially-produced dry feeds. There were no differences in performance between fish kept on LD16:8 and LD12:12 photoperiods. Feed conversion ratios (FCRs) were relatively poor, ranging from 1.45-2.09. It appears that the poor FCRs were related to food wastage (fish were fed on a % body weight basis) and overcrowding.

Halibut in growout cages at HDL were initially fed a moist, herring-based diet made by HDL. Tests with various commercially-produced dry feeds were proposed.

**Fish Health**

Samples of water, algae, live feeds, and fish from hatcheries were analyzed, primarily by the Research and Productivity Council (RPC) and the Atlantic Veterinary College (AVC). Investigations were conducted into larval and juvenile mortalities.

Algae and live feeds (rotifers, *Artemia*, wild zooplankton) were highly contaminated with bacteria, but these bacteria did not appear to be associated with larval and juvenile mortalities. Bacteria were found to be associated with most (but not all) larval and juvenile mortality events. An incidence of an atypical *Aeromonas salmonicida* occurred in juvenile halibut at MMI in 1998; the infection was cleared up by antibiotic treatment. *Vibrio* and *Marinomonas* were found to be associated with larval halibut mortalities.

***Other Halibut Production Projects (not funded by the New Finfish Aquaculture Species Development Program)***

MMI was also involved in another juvenile halibut production project at the Ocean Sciences Centre near St. John's, NF. This project was started in 1997, in collaboration with Memorial University of Newfoundland and the Canadian Centre for Fisheries Innovation (Raymond 1998).

Scotian Halibut Ltd. (a partnership between the Icelandic company Fiskey and Nova Scotian partners) is based at Clark's Harbour and Woods Harbour, NS. This operation imported 50,000 juvenile halibut from Iceland from each of the 1998, 1999, and 2000 year-classes, for growout in land-based recirculation tanks. Local broodstock were also collected and a hatchery was under construction in 2000, with the first egg collection expected in the spring of 2001.

***Summary of Major Accomplishments and Future Research Priorities***

Broodstock were collected, maintained, and spawned. Spawning techniques were improved, including the use of photothermal manipulation to advance the spawning season. Two hatchery production projects were supported and both produced juveniles. Early rearing problems were encountered at both sites, especially at the yolk sac and start-feeding stages, but survival has improved. Growout trials were started in modified sea cages, tanks, and raceways. It appears that 3 years of growout are required to reach a market size. Advancements were made on diet development, but more research is required. Nearly 100% pigmentation was achieved at both hatcheries.

The New Brunswick Department of Agriculture, Fisheries, and Aquaculture indicated the following research priorities for 2000-2005:

*Growout trials*

- Establish the requirements of halibut in a growout facility. The feasibility of using land-based recirculation facilities for growout should also be investigated.

*Broodstock program*

- Development of faster growing strains of halibut and further advancement of the spawning period.

*Hatchery techniques*

- Develop a standard hatchery protocol to increase survival and growth rates and decrease costs.

*Diet and feeding strategies*

- This should include research into the use and required composition of artificial diets for larvae, juveniles and adults.

*Fish health*

- Disease prevention, identification and treatment.

## HADDOCK (*Melanogrammus aeglefinus*)

### *Background*

Growout trials using juvenile haddock in salmon cages were initiated in 1991 at Campobello Island (Henry 1997). Research on haddock culture began at the St. Andrews Biological Station (SABS) in the early 1990s, led by K. Waiwood. This research included wild broodstock collection and maintenance and spawning trials in tanks. The first production of cultured haddock was in 1993, when 63 juvenile haddock were produced at SABS (Waiwood 1994). Some of these were later transferred to sea cages at Harbour DeLoutre Products Ltd. (HDL, Campobello Island, NB) for growout trials. Litvak (1998) summarized progress in haddock culture up to 1997.

### *Research supported by the New Finfish Aquaculture Species Development Program*

The Program initially provided funds for research on early rearing methods at SABS, the Huntsman Marine Science Centre (HMSC), and the NBDFA Aquarium and Marine Centre (AMC). Starting in 1997, support was provided to a multi-partner production project, involving egg production at SABS and AMC, juvenile hatchery production at AMC and the National Research Council Institute for Marine Biosciences (NRC-IMB), and growout in sea cages at the salmon farm of Connors Bros., Ltd. (CBL) at Fairhaven, Deer Island, NB. Other research was supported on broodstock, early rearing, nutrition, and fish health.

#### Broodstock and Reproduction

The Program supported the holding of haddock broodstock at sites in New Brunswick and Nova Scotia. At the start of the Program, broodstock were already being held at SABS, HMSC, HDL, and AMC. Using the DFO vessel *CCGS J.L. Hart*, additional broodstock were collected, primarily off southwestern Nova Scotia, in the fall of each year of the Program in a collaborative project involving NBDFA (St. George) and DFO (SABS). A total of over 400 haddock were collected or purchased and transported to the various broodstock facilities. In addition, 40 cultured haddock from the 1997 year-class production at CBL were transferred to SABS and spawned in 2000. The approximate numbers of broodstock being held at the main holding sites in early 2000 are shown in the following table. Juveniles produced at the various sites were also being held for use as future broodstock.

| *Broodstock facility* | *Approximate numbers of broodstock (early 2000)* |
|---|---|
| SABS (flow-through tanks) | 160 |
| HDL (sea cages) | 100 |
| AMC (recirculation tanks) | 78 |
| NRC (flow-through tanks) | 50 |

SABS and AMC were the main egg production facilities for the Program. There was also some egg production at NRC-IMB (Sandy Cove, NS). Funds were provided by the Program to upgrade the broodstock facilities at SABS and AMC. Haddock were kept communally in large tanks and allowed to spawn naturally (hormonal injection is not required). Fertilization rates were reported to be consistently >80%. Fertilized eggs were gathered from the water surface with collectors. SABS and AMC broodstock facilities used ambient and advanced photoperiod and temperature regimes, which allowed spawning to extend from December-May in the 1999-2000 season (under ambient conditions, spawning began in March). Earlier egg production allowed egg incubation during the more suitable colder water temperatures in February-March. The annual steroid profiles and gonadal development of broodstock

held under ambient and phase-shifted photoperiods were examined (collaboration between D. Martin-Robichaud, SABS, and D. Berlinsky, University of Rhode Island). The NRC broodstock were kept under ambient temperature and photoperiod.

Starting in 1999, haddock eggs produced at SABS and AMC were incubated 7-10 days prior to transport, in order to minimize mortalities during transport of the early developmental stages.

Research was conducted at SABS on paired mating, which would allow production of viable eggs from specific families or pedigrees. Eggs were produced from paired matings in small tanks, but fertilization rates were poorer than that found for cod (Trippel et al. 1998). Certain spawning pairs outperformed others. Eggs with low ash content (<20%) had higher fertilization and hatching rates, but there was no correlation between percent dry matter, lipid or fatty acid composition and egg quality (Trippel et al. 2000).

In research not financially supported by the New Finfish Aquaculture Species Development Program, E. Trippel (SABS) and P. O'Reilly (Dalhousie University) were examining kinship among progeny of communally spawned haddock and the implications for inbreeding potential.

**Larval and Juvenile Production**

Hatching rates at NRC and AMC hatcheries (using eggs from SABS and AMC) averaged 80-90% in 1999 and 2000. This was an improvement over previous years and was attributed to disinfection and incubation protocols implemented at the egg production facilities.

The main juvenile production facilities were at AMC (led by C. Lanteigne) and NRC-IMB Sandy Cove (led by S. Johnson, B. Blanchard, and S. Leadbeater). Standard production methods were developed, including larval densities, live feed production, feeding strategies, flow rates, temperatures, and tank types. The tank types, densities, and temperatures used for various stages in 1999-2000 were:

| *Stage* | *AMC Shippagan, NB* | *NRC-IMB Sandy Cove, NS* |
|---|---|---|
| Egg incubation (about 14 days total) | 0.25 $m^3$ cylindroconical upwelling incubators (flow-through) @ 1-3 eggs/mL; 7°C | 0.1 $m^3$ cylindroconical upwelling incubators (flow-through); 6-7°C |
| Larvae (hatching through weaning: about 55-60 days duration) | 1.2 $m^3$ circular tanks (flow-through) @ 200 larvae/L; 7-12°C | 3.5 $m^3$ cylindroconical tanks (flow-through); 10-13°C |
| Juveniles (post-weaning to ~5 g) | 1.2 $m^3$ circular tanks (flow-through and recirculation) @ 5-7 juveniles/L; 12-16°C | 0.2-4.0 $m^3$ tanks (flow-through) @ 0.5-2.5 juveniles/L |

Juveniles (approximately 3-5 g) ready for transfer to sea cages could be produced in about 4-6 months. Estimated juvenile production figures are shown in the following table. In addition, smaller numbers were produced each year at SABS, primarily for research purposes.

| *Facility* | *Weaned juvenile haddock production by year-class (for transfer to sea cages)* | | | |
|---|---|---|---|---|
| | *1997* | *1998* | *1999* | *2000* |
| AMC | 1,000 | 5,000 | 35,000 | 40,000 |
| NRC-IMB Sandy Cove | - | 11,000 | 27,500 | 57,000 |

Juvenile production improved at both NRC-IMB and AMC. A key constraint continued to be high mortalities between hatching and weaning, especially in the first 20 days post-hatch. AMC also reported high mortalities between 20-40 days post hatch and NRC reported high mortalities during weaning (introduction of formulated feeds started at 37-45 days post-hatch). Cannibalism among juveniles can be a problem: regular grading of fish is required to prevent this problem. In 1999 AMC reported 1.9-2.8% survival to weaned juveniles (to 70 days post-hatch), while NRC reported 0.15-5% (average <0.5%). In 2000, the survival rate to the weaned juvenile stage averaged 1-3% at the 2 hatcheries. AMC reported that survival at the end of weaning was 6 juveniles per litre (with an objective of 10 juveniles per litre). Based on the research conducted at AMC and NRC, a preliminary economic model for a haddock production hatchery was prepared by Fundy Engineering & Consulting Ltd.

L. Kling also conducted Early rearing research at the University of Maine at Orono, using eggs supplied by the Program (from SABS). Survival of early larval stages was found to be higher in moving water than in static conditions. Intensive culture was achieved in both flow-through and recirculating seawater systems, with better results obtained with recirculation. Larvae were found to be sensitive to sudden fluctuations in temperature, oxygen, and ammonia. Haddock larvae grew faster than cod larvae reared under similar conditions, but survival during the first 3 months was much lower. High mortality was observed immediately after hatching, between 8-15 days post-hatch, and during weaning.

Research started at HMSC and later transferred to the University of New Brunswick at Saint John (UNBSJ) found that there were significant effects of light on the early life history stages of haddock, but the effects varied with developmental stage (G. Downing and M. Litvak; see Downing 2001, Ph.D. thesis):

- photoperiod influenced embryonic development: diel periodicity in light and dark exposure produced larger size-at-hatch. However, there were no differences in larval growth or survival between a simulated ambient photoperiod and continuous light (Downing and Litvak 1999b);
- larval survival and growth were higher at a higher light intensity (110 lux versus 5 lux; Downing and Litvak 1999a);
- light intensity and its interaction with tank color influenced larval growth and survival: survival was greater in white versus black tanks; growth was poorer under conditions that likely contributed to poor prey:background contrast (e.g. low light intensity and dark tank color; Downing and Litvak 1999b); and
- successful initiation of first feeding by larvae was greatest under a blue light comparable to that found in the ocean. However, this did not translate into improved larval growth, possibly due to the high food concentration in the experimental culture conditions (Downing and Litvak 2001).

**Growout**

Growout trials by CBL (led by C. Frantsi) began with the 1997 year-class production. Juveniles from AMC were transferred in July 1997 (at 2-15 g) to a nursery facility at HMSC (land-based, flow-through tanks). In September 1997, these fish (8-30 g; average 25 g) were then transferred to 12-m square steel salmon cages (6-m depth) at CBL's Fairhaven salmon farm. The cages required small mesh (0.5 inch) nets, because of the small size of the juveniles. The net included a sun screen to prevent sunburn problems. Considerable losses occurred initially, due to predation by otters and mink. A covering, made of the same heavy twine as the net cage, was required to protect fish from these predators.

The 1998 year-class juveniles were transferred directly from the two hatcheries to square steel cages at CBL, beginning in June 1998 (mostly 3-5 g), eliminating the need for a separate nursery facility. The 1999 and 2000 year-class juveniles were also transferred directly from the hatcheries to sea cages at CBL.

The approximate numbers and average weights of haddock remaining in March 2000 are shown in the following table. The final average weight of the 1997 year-class did not accurately reflect the growth rate, because of the high number of losses due to predators that selectively preyed on larger fish. About half of the remaining 1997 year-class fish were transferred to SABS for use as future broodstock and the remainder were to be used for processing/yield trials.

| *Year-class* | *Number of fish (March 2000)* | *Average weight, g (March 2000)* |
|---|---|---|
| 1997 | 90 | 1,400-2,300 |
| 1998 | 15,000 | 400-1,100 |
| 1999 | 54,000 | 100-200 |

Results from the CBL trials suggested that the most likely growout scenario is to transfer 3-5 g juveniles from the hatchery to "juvenile" sea cages (6 m square cages, 2 m deep, with 0.5 inch mesh) in May-June. The fish would remain in the juvenile cages until they reach 25+ g. In July, they would be transferred (at lower densities) to "market" cages (12 m square cages, 6 m deep, with 1.375 inch mesh), where they would be grown to market size, which is estimated to be approximately 2-3 kg (about 3 years post-hatch).

The first cultured haddock were to be marketed in early 2001, from 1998 year-class fish. There remain several unknowns before this species can be fully commercialized. These include: market size, impact of maturation, stocking density, quality at market size, feeding strategies, low cost feed formulations for all stages, feed conversion ratios, and full production costs.

Research at NRC-IMB (in collaboration with CBL and SABS) on freeze resistance of haddock showed that juveniles and adults were not biochemically equipped to avoid freezing in icy seawater. This would mean that haddock could be susceptible to cold temperature mortalities at sea cage sites where winter water temperatures fall below 0°C (Ewart et al. 2000).

Research (not financially supported by the Program) was conducted on the use of lights to enhance growth. Tank trials at SABS (E. Trippel) in 1998 and 1999 using post-juveniles (year one fish) showed improved growth in extended daylength, compared to ambient lighting. Some field trials using submersible lights were initiated at the CBL Deer Island site, but have not yet demonstrated beneficial effects. A negative effect reported was an increase in numbers of the parasite *Cryptocotyle* sp. It is anticipated that submersible lights will be utilized periodically at sea cages to depress maturity and enhance growth of haddock.

**Nutrition**

A moist haddock broodstock diet was developed by NRC-IMB (S. Lall) and manufactured by Connors Bros., Ltd. (CBL). Haddock broodstock were fed this diet, as well as dry marine finfish broodstock pellets and frozen fish, squid, and shrimp.

Hatchery projects at UNBSJ, AMC and NRC used "green" water (the microalgae *Isochrysis galbana* Tahitian strain), enriched rotifers and enriched *Artemia*. At SABS, larvae were first fed "green" water, followed by wild zooplankton (including wild rotifers). Trials at the University of Maine were conducted without "green" water, using various rotifer enrichments. A preliminary trial by NRC-IMB indicated that rotifer enrichment may not be beneficial (and may actually be harmful) to larval growth and survival. The optimal enrichment strategy for live feeds for larval haddock remains to be determined and further research was being conducted at NRC-IMB and SABS.

Research by D. Nanton (Dalhousie University) and J. Castell (DFO) found that haddock larvae (average initial lengths 3.5 mm) grew better, but did not survive as well from 0-18 days post-hatch, when fed the harpacticoid copepod *Tisbe* sp., compared to live rotifers (Nanton and Castell 1998a). Because *Tisbe* is a benthic detritivore, which sinks to the bottom of the tanks, it would be less available to the planktonic haddock larvae. *Tisbe* may serve better as a tank cleaner and a diet supplement, rather than as the sole live feed diet.

Some problems were experienced with commercially available dry weaning diets at both AMC and NRC. Research at NRC-IMB (S. Lall) determined nutrient requirements (particularly amino acids, lipid, and trace elements) of early stages of haddock. A semi-moist weaning diet was prepared and compared with 3 commercially available weaning diets for marine fish. Two of the commercial diets produced good results, but the other was less satisfactory. The NRC diet has a lower lipid level than the commercial weaning diets and can be produced at relatively low cost.

Research led by C. Hebb (Nova Scotia Agricultural College and Dalhousie University), in collaboration with DFO, found no significant differences in growth rate, feed efficiency, or protein efficiency among juvenile haddock (average initial weights 5.4 g; average final weights 22-24 g; 8-week study) fed isocaloric diets with protein:lipid ratios of 50:10, 50:20, 45:15, and 40:20%. There was no evidence of fatty livers at the higher lipid levels. It was suggested that a diet containing 40% protein and 20% lipid (22 g digestible protein per MJ digestible energy) would allow for good growth, while costing less to produce (Hebb, M.Sc. thesis 1998).

Research was also continuing at NRC-IMB (S. Tibbetts, S. Lall, and J. Milley) to determine optimum dietary protein and lipid levels for juvenile haddock. Preliminary results from a 12-week trial comparing protein levels of 45-55% and lipid levels of 10 and 15% indicated that optimum growth and feed conversion ratios for juvenile haddock (average initial weights 13.5 g) were obtained with high levels of protein (55%) and low levels of lipid (10%). The NRC research found that dietary lipid levels of 15% resulted in enlarged fatty livers in juvenile haddock. Analysis of plasma lipoproteins indicated that haddock have a limited ability to transport large amounts of deposited fat out of the liver to the muscle for storage. This would suggest that haddock feeds must be formulated with lower fat levels than salmon feeds. Research was continuing at NRC to further examine the effects of dietary lipid on fatty liver condition and lipid transport in juvenile haddock. The differences in results between the different studies may be due to differences in protein and lipid sources, different initial fish weights, and possibly other differences in the experimental methods. More research on the nutritional requirements of juvenile haddock is required.

The NRC research also indicated that soybean and corn gluten could partially replace herring meal in the diet of juvenile haddock, while crab meal may be a good supplement to enhance palatability and reduce carbohydrate levels in feeds. NRC also initiated research on phosphorus requirements, deficiency signs, and urinary excretion in juvenile haddock. The phosphorus requirement of juvenile haddock was estimated to be 0.33 g available phosphorus per MJ digestible energy. Phosphorus deficiency signs included poor growth, loss of appetite, poor bone mineralization, and deformed vertebrae. Further research was continuing in 2000-2001.

Growout feeding trials were conducted at CBL in 1998 using a CBL-produced moist salmon feed variation. Further diet development work was conducted at NRC-IMB, led by S. Lall. A dry growout feed was formulated, but the first feed lot had a higher than specified fat level (23% actual versus 14% specification) due to difficulties encountered in manufacturing the low fat feed. The haddock given this feed lot developed fatty livers. Reduction of fat levels in the feed appeared to have reduced the occurrence of fatty livers in subsequent year-classes (but did not reduce livers in fish with already enlarged livers), although further testing is required. NRC examined the digestibility and nutritional

quality of the commercially produced haddock grower diet and suggested changes in the digestible protein:energy ratio to improve the existing feed formula and specifications. The modified grower diet was in use at the CBL growout site. In March 2000, CBL reported feed conversion rations (FCRs) of 1.08 for 1999 year-class fish and 1.20 for 1998 year-class fish in sea cages.

**Fish Health**

Samples of water, algae, live feeds, and fish from hatcheries were analyzed, primarily by the Research and Productivity Council (RPC) and the Atlantic Veterinary College (AVC). Investigations were conducted into larval and juvenile mortalities.

Algae and live feeds (rotifers, *Artemia*, wild zooplankton) were highly contaminated with bacteria, but these bacteria did not appear to be associated with larval and juvenile mortalities. Rotifers were found to harbor protozoans that were also found in the guts of haddock larvae.

High mortalities of larvae typically occurred in the first 20 days post-hatch, and less consistently after 20 days post-hatch. Bacteria appeared to be associated with these mortalities, particularly *Vibrio* spp., a species tentatively identified as *Sulfitobacter* (or *Roseobacter*), *Marinomonas*, and *Aeromonas*. In spring 2000, RPC sampled haddock larvae at AMC weekly from hatching to weaning. The bacterial profiles of the haddock larvae were initially dominated by a higher diversity of bacteria, followed by succession from a putative *Marinomonas* sp. to dominance by the species identified as *Sulfitobacter* sp.

The histology of haddock eggs and larvae from SABS and AMC was examined using light and electron microscopy. Eggs were found to be clean at spawning, but were covered with a layer of bacteria and other organisms and mucous at hatching. Comparisons between normal and abnormal development were made to aid in the monitoring of fish health (Morrison et al. 1997, 1999).

Gas equilibration problems were encountered in haddock broodstock at SABS. These problems were rectified through installation of degassing and oxygen injection in the seawater system.

***Summary of Major Accomplishments and Future Research Priorities***

Broodstock were collected, maintained, and spawned. The spawning season was advanced, using photothermal manipulation. Incubation and disinfection of eggs prior to transport improved hatching rates. Early rearing survival improved but further improvements are required between hatching and weaning and during weaning. Research was completed on optimal light conditions and tank color for larval growth and survival. Growout trials indicated that 3 years (post-hatch) are required to reach a market size. A cage and net system with a predator avoidance system was developed for growout. Fatty livers were encountered, probably related to a low lipid requirement in haddock. Weaning and growout diets with lower lipid levels were developed and tested. A number of standard operating procedures for haddock culture were developed.

The New Brunswick Department of Agriculture, Fisheries, and Aquaculture indicated the following research priorities for 2000-2005:

*Larval and juvenile diets*

- 0 to 20 days post-hatch haddock and weaning haddock (approximately 35 days post-hatch) diets. This includes research into the use and required composition of artificial weaning diets (e.g. microdiets).

*Cannibalism*

- Reduction of cannibalism among juvenile haddock will substantially improve hatchery survival rates and reduce costs.

*Juvenile production*

- To ensure a supply of juveniles for grow-out trials, a juvenile production program should be supported in 2001.

*Feeding rates and light levels*

- Determine optimal conditions for growth in marine cage sites.

*Fish health*

- This includes research into disease prevention, identification and treatment. In particular, the susceptibility of haddock to diseases that affect farmed salmon (e.g. Infectious Salmon Anemia) should be investigated.

*Broodstock program*

- Development of faster growing strains of haddock and further advancement of the broodstock-spawning period so that larger fish can be ready to enter marine cage sites each May.

## WINTER FLOUNDER (*Pseudopleuronectes americanus*)

### *Background*

The Huntsman Marine Science Centre (HMSC) began research on winter flounder culture in 1992, in conjunction with Harbour DeLoutre Products Ltd. (HDL) on Campobello Island, NB. This work (led by M. Litvak) included growout studies in modified salmon cages and laboratory research on spawning and early rearing techniques. Studies were also conducted on weaning of juveniles on dry diets (Lee and Litvak 1996a,b). This early work suggested that winter flounder were already close to the commercialization stage. This encouraged Sambro Fisheries Ltd. to begin work on winter flounder culture starting in 1994 (Batt 1998). Litvak (1994, 1996, 1999) described current techniques used in winter flounder culture. The natural ability of winter flounder to produce anti-freeze proteins makes this species a good candidate for culture in colder waters.

### *Research supported by the New Finfish Aquaculture Species Development Program*

The Program supported broodstock holding and research on hatchery production, nutrition, and fish health issues.

#### Broodstock

Winter flounder broodstock were initially held at HMSC and HDL in New Brunswick and Sambro Fisheries Ltd., near Halifax in Nova Scotia. In 2000, HMSC was the only facility still holding broodstock for the Program, with 50 winter flounder broodstock, as well as 34 yellowtail flounder (*Limanda ferruginea*) broodstock, and small numbers of other small flounder species. All species were held in flow-through tanks under ambient conditions. In 1999, winter flounder at HMSC were spawned in May and yellowtail flounder in late May-June.

**Larval and Juvenile Production**

The Program funded hatchery research at HMSC and UNBSJ (led by M. Litvak) in 1995-96 and 1996-97 and at Sambro Fisheries Ltd. (research led by J. Batt) in 1997-98, in collaboration with M. Litvak and J. Castell (DFO). In 1999-2000, support was provided to a new winter flounder hatchery project at HMSC (led by V. Puvanendran).

Litvak (1999) reported that hatching rates usually exceeded 90% using previously developed methods of spawning and egg collection. Winter flounder eggs are negatively buoyant and adhesive. Diatomaceous earth was added to prevent clumping of eggs.

Winter flounder juveniles were produced at HMSC (M. Litvak) in 1995 and 1996. Eggs were incubated in static or flow-through trays. Larvae were reared in 0.1-$m^3$ cylindroconical upwelling tanks (about 20 larvae/L). Metamorphosed juveniles were reared in raceways, circular tanks, and in cages suspended in tanks. Relatively high survival (averaging about 50%) was reported through metamorphosis, but high mortalities occurred immediately after metamorphosis. Bacterial and fungal infections related to water quality and dietary problems appeared to be the main factors. Juvenile production was about 1,400 in 1995 and 2,400 in 1996, with survival rates from hatched larvae to juveniles of about 5%.

Litvak (1999) found that winter flounder larvae reared under a continuous light regime grew faster, reached metamorphosis sooner, and showed higher survival, compared to a natural photoperiod. Light intensity (from 5-200 lux), however, did not affect larval growth or survival. Casey (M.Sc. thesis 2000) found that juveniles reared under continuous light grew twice as fast as those reared under a LD12:12 photoperiod, and that juveniles grew faster at 15°C than at either 10 or 20°C. Larvae and juveniles grew much faster under culture conditions than in the wild (Litvak 1999).

Sambro Fisheries Ltd. (research led by J. Batt) also produced small numbers of juveniles starting in 1995, using the methodology developed by M. Litvak (see Batt 1998). Some bacterial and fungal problems were reported: all of the juveniles produced in 1997 died as a result of a *Vibrio* infection. Sambro Fisheries Ltd. continued some work until 1999, but later decided to discontinue its winter flounder aquaculture program.

The new winter flounder project at HMSC (led by V. Puvanendran) began production in 1999. Broodstock were spawned in mid-May. Larvae were kept in 0.3 $m^3$ conical bottom tanks and juveniles in 1.1-m circular and rectangular tanks. Survival from hatched larvae through metamorphosis was 80-90% (total production 110,000 fish), but there was >90% mortality during and post-weaning, and only 7,500 juveniles survived to May 2000 (about 5% survival from hatched larvae). The high mortality rates were thought to be due to stress caused by on-going construction in the facility; lack of temperature control, resulting in high summer water temperatures (15-16°C) approaching the upper lethal limit for these fish; poor quality tanks; and/or dietary problems. Malpigmentation rates were 15-20%.

The HMSC project also produced juvenile yellowtail flounders in 1999. Broodstock were spawned in mid-May. Survival from hatching through metamorphosis was about 15% (about 10,000 fish produced). Mortality during weaning was about 50%. About 4,000 juveniles survived to May 2000 (about 6% survival from hatched larvae). Malpigmentation rates were 50-90%. These high malpigmentation rates were thought to be due to inadequate enrichment of rotifers and *Artemia*. Enrichment trials were planned for 2000.

**Growout**

Growout trials were on-going or proposed at various sites in southwestern New Brunswick, using sea cages, bottom culture in lobster pounds, and land-based tanks (see Litvak 1999).

**Nutrition**

Winter flounder larvae in the hatcheries were first fed "green" water (*Isochrysis galbana*), enriched rotifers, and *Artemia*. Litvak (1996, 1999) initially also included trochophores, but it was found that their presence did not improve larval survival, and their use was discontinued. Blair et al. (1998a) studied the influence of several enrichment media on the composition of rotifers and the subsequent effects on survival and lipid content of larval winter flounders. The survival of the fish larvae appeared to be directly related to the levels of docosahexaenoic acid (DHA) in the enriched rotifers.

A reference diet for juvenile winter flounders was developed and tested by J. Castell (DFO). The juveniles showed much better growth and feed consumption with this reference diet, in comparison to 5 commercial diets for marine fish. C. Hebb (Nova Scotia Agricultural College and Dalhousie University), in collaboration with DFO and Sambro Fisheries Ltd., conducted research to further develop juvenile winter flounder diets. Juveniles (initial weight 0.8 g; 10-week study) were fed isocaloric diets with protein:lipid ratios of 50:10, 45:15, and 40:20%. Winter flounder fed the highest protein diet (50:10 protein:lipid or 27 g digestible protein per MJ energy) had the highest growth rate, feed efficiency, and protein efficiency. However, it was also found that alternate protein sources (soybean meal, canola meal, and canola protein concentrate) could be used to substitute for fish meal at levels of up to 30% of the diet (Hebb et al. 1997; Hebb, M.Sc. thesis 1998).

Research was also conducted on methods of fecal collection used in evaluating protein digestibility by winter flounder (Ramsay et al. 2000). The results indicated that further research is required to determine the most practical method. This study also showed no differences in crude protein or gross energy digestibility among test diets containing 15% canola protein concentrate, soybean meal, or fish meal. These results indicate that soybean meal and canola protein concentrate have potential as alternatives to fish meal in diets for winter flounder, but further research is required.

Collaborative research, involving DFO (J. Castell), Sambro Fisheries Ltd. (J. Batt), and Dalhousie University (M. Fredette), was conducted on the use of feeding stimulants to increase palatability and feed acceptance for juvenile winter flounder. Results testing crab meal as a feeding stimulant were inconclusive. FinnStim®, a commercial feeding stimulant, was found to be an effective feeding stimulant for juvenile winter flounder when added to feed at the 1% level (Fredette et al. 2000).

A study by NRC-IMB described the sequence of molecular, biochemical, and histological events related to the functional development of the winter flounder stomach. The results suggested that stomach is at an advanced stage of development and functionality at the generally practised time of weaning, indicating that weaning to formulated feeds could be initiated earlier (Douglas et al. 1999).

**Fish Health**

Juvenile mortality problems occurred at all facilities. These appeared to be related to bacterial or fungal infections (see above).

Research was conducted by B. MacKinnon (University of New Brunswick, Fredericton) on the potential impact of the digenean parasite *Stephanostomum baccatum* on cultured winter flounder. The results suggested that inshore sites would have reduced chances of infection, compared to deeper water sites.

Antibodies against this parasite were found in winter flounder blood samples, indicating that fish may respond to a preventative vaccine. Some winter flounder in culture conditions have been infected with the trematode parasite *Cryptocotyle lingua*.

### *Summary of Major Accomplishments and Future Research Priorities*

Winter flounder broodstock were collected, maintained, and spawned. Larval and juvenile rearing systems were developed. High mortalities were encountered in early rearing, especially after metamorphosis (during and after weaning). Winter flounders require relatively high protein levels in their diets, but alternate protein sources can probably be used for some of this requirement. The various problems encountered indicate that winter flounder aquaculture is not as close to commercialization as was previously thought. Some research was also done on yellowtail flounder culture.

The New Brunswick Department of Agriculture, Fisheries, and Aquaculture indicated the following research priorities for small flounders for 2000-2005:

*Juvenile production*
- This will allow grow-out trials to take place.

*Growout trials*
- Establish the requirements of flatfish in a grow-out operation.

*Hatchery techniques*
- Standard protocols and optimal rearing strategies should be developed.

*Species selection*
- Flatfish species best suited to commercial aquaculture must be identified.

*Broodstock program*
- Develop faster growing strains of small flounders and determine care requirements (e.g. nutrition). Emphasis should also be placed on advancing the spawning period.

*Fish health*
- Disease susceptibility, prevention, identification and treatment.

## STRIPED BASS (*Morone saxatilus*)

### *Background*

Research and growout trials on striped bass culture have been conducted at various sites in eastern Canada since the 1980s (Cairns et al. 1999). Research at the St. Andrews Biological Station (SABS) began in 1988, when wild broodstock were collected and held. These fish were spawned annually starting in 1991. Early research looked at spawning techniques (requiring hormonal induction) and optimal conditions for eggs, larvae, and juveniles in both intensive tank culture and extensive pond culture (Harmon and Peterson 1994; Peterson 1991, 1994b; Peterson et al. 1996b). Larval rearing trials at the Huntsman Marine Science Centre (HMSC) indicated that growth and survival were best in brackish water and relatively high (>15°C average) water temperatures (Hogans 1997).

This research identified certain problems, which needed to be addressed if striped bass culture were to be successful in the Maritimes. One problem was that because this species grows best at warmer temperatures, the growing season (at ambient temperatures in the Maritimes) is relatively short. On the

other hand, striped bass strains from the Maritimes appear to grow faster at a given temperature, probably as an adaptation to the shorter growing season (Peterson et al. 1997).

***Research supported by the New Finfish Aquaculture Species Development Program***

Striped bass broodstock were initially held at SABS, HMSC, and the NBDFA Aquarium and Marine Centre (AMC). SABS and HMSC produced eggs, sperm, and larvae for research and production trials. The SABS broodstock were transferred to HMSC in 1998. Temperature and photoperiod manipulations were used to advance the spawning period of the broodstock, so that larvae could be produced earlier in the year (April versus May-June).

A low rate of swimbladder inflation (sometimes as low as 10%) was a major problem in the production of viable juveniles. Research at SABS looked at ways of increasing the success rate for swimbladder inflation in larvae. The use of black tanks (versus white tanks) and shorter photoperiods (LD8:16 versus LD16:8) was found to result in higher swimbladder inflation rates (Martin-Robichaud and Peterson 1998).

Research on larval and juvenile striped bass (Stewiacke River strain), led by J. Duston at the Nova Scotia Agricultural College (NSAC), was supported starting in 1997. Research findings included:

- enrichment of *Artemia* prey with highly unsaturated fatty acids (HUFAs) resulted in no improvements in survival or growth of larval striped bass. This suggests that this local strain can produce its own HUFAs, which is more typical of freshwater fish than marine fish (and is different than U.S. strains of striped bass);
- gastric evacuation rates indicated that larvae should be fed a minimum of 2-3 times per day;
- the minimum light threshold for larval feeding is about 1 lux, indicating that larvae can feed effectively at dawn and dusk. Food capture in darkness was poor and light intensity >1,000 lux was stressful and did not improve feeding rates. Feeding rates appeared to be optimal at around 100 lux; and
- water velocities between 1 and 3 body lengths per second had no significant effect on the growth rate or feed conversion ratio of juveniles.

Other research at NSAC examined the effects of light intensity and turbidity on prey capture by larval striped bass. For larvae less than 15 days post-hatch, prey capture (*Artemia*) was better in turbid water and independent of light intensity (20 lux versus 2 lux). In contrast, for larvae after 15 days post-hatch, prey capture was better at the higher light intensity and independent of turbidity. These results suggested that for larvae less than 15 days post-hatch, low light intensity and turbid water may improve survival and growth by increasing feeding rates, while after 15 days post-hatch, light intensity should be progressively increased and turbidity decreased (White 2001, M.Sc. thesis).

In the NSAC freshwater recirculation system at 20-22°C and using a commercial salmon diet, the optimum ration for juveniles (30-50 g) was 3-4% body weight per day, with a feed conversion ratio of 0.9-1.1 (Duston et al. 2001). This was lower than the 10% body weight per day recommended by Peterson et al. (1996d) for 25-50 g juveniles at 22°C and 15 ‰ salinity in flow-through tanks at SABS. Peterson et al. (1996d) also reported that growth was faster at 15 ‰ than in freshwater.

A striped bass culture manual was produced by Peterson et al. (1996d), with publication costs provided by this Program. This manual suggested that in the Maritimes, striped bass could be grown out in brackish water ponds for 18 months, with a target size of about 600 g. A larger product could be attained with another year in ponds or a summer of growout in sea cages. In comparison, the research at NSAC suggested that pan-sized (400-600 g) striped bass could be produced in 12 months (from the egg stage) in

freshwater recirculation tanks at 20-22°C (Duston et al. 2001). Higher growth rates may be possible at higher temperatures and salinities.

One fish health problem was reported by the NSAC project. A disease caused by *Pseudomonas* spp. resulted in 25% mortality and loss of appetite for 2 weeks among survivors. The disease occurred after fish were handled twice in 2 days (Duston et al. 2001).

There have been several attempts at striped bass culture in eastern Canada, but with limited success (Cairns et al. 1999). There is one operation at Stewiacke, NS, that has been producing small numbers of market-size striped bass in brackish water earthen ponds since about 1994. In 2000, this operation produced an estimated 50,000-100,000 juveniles from spawning of its own broodstock in indoor tanks. The company plans on growing out those juveniles that can be accommodated in its ponds, and would like to sell the surplus juveniles to other interested growers (R.H. Peterson, pers. comm.).

### *Summary of Major Accomplishments and Future Research Priorities*

The spawning season was advanced using photothermal manipulation. Swimbladder inflation success rates were improved through tank color and photoperiod manipulation. Research was conducted on dietary requirements, feeding strategies, and growout strategies.

The New Brunswick Department of Agriculture, Fisheries, and Aquaculture proposed no further research on this species.

## AMERICAN EEL (*Anguilla rostrata*)

### *Background*

Eel aquaculture is a large industry in Asia, and is growing in northern Europe. Eel culture depends on the collection of wild elvers or juveniles, which are then grown to market size under culture conditions. Elvers are grown-out in recirculation systems in relatively warm temperatures in order to accelerate growth.

A small fishery for elvers has existed in the Maritimes for about a decade. The wild elvers are caught in the spring and are exported to Asia for growout. A suggested strategy for increasing the value of this industry is to grow out the elvers to a larger stage (2-10 g) prior to export overseas in the fall. Alternatively, juveniles could be grown-out to market size.

In 1993-94, research was conducted at the St. Andrews Biological Station (SABS) on first feeding and growth of elvers at different temperatures (Peterson and Martin-Robichaud 1994).

There remain several problems to overcome, if this industry is to expand. Under culture temperatures, about 90% of cultured eels become males, while the larger females are favored in some markets. Another problem is the difficulty in weaning elvers onto prepared diets (Peterson 1994a).

For a time, in the late 1990s, there were 3 commercial eel production facilities in the Maritimes, but only one, at Port Elgin, NB, remained in operation in 2000. This facility produces both juveniles and market-

size eels. Other eel culture facilities have recently been started or proposed in Nova Scotia and Newfoundland.

### *Research supported by the New Finfish Aquaculture Species Development Program*

The Program supported an investigation at SABS in 1995-96, which examined the hypothesis that low temperature exposure during the first winter would produce a higher percentage of females, which, as mentioned above, are preferred in some markets. Laboratory trials using various thermal treatments proved unsuccessful in producing higher percentages of females, suggesting that temperature may not be the main factor in determining sex (Peterson, et al. 1996a,c).

A project at the Nova Scotia Agricultural College (NSAC) examined 5 isoenergetic diets, ranging from 35-51% crude protein, for juvenile eels (initial weight 8 g; 84-day study). Based on the results, it was recommended that juvenile eel diets should contain approximately 47% crude protein (22 g digestible protein per MJ digestible energy) for optimum growth and feed utilization (Tibetts, M.Sc. thesis 1999; Tibetts et al. 1998, 2000). These results indicated that commercial eel grower diets were providing protein in excess of that required, so it should be possible to produce more efficient, cost-effective diets which result in less nitrogenous waste production, which is especially important in recirculation facilities.

### *Summary of Major Accomplishments and Future Research Priorities*

Research indicated that winter water temperature was probably not the main factor in sex determination. Nutritional requirements for juveniles were investigated.

The New Brunswick Department of Agriculture, Fisheries, and Aquaculture proposed no further research on this species.

## SHORTNOSE AND ATLANTIC STURGEON (*Acipenser brevirostrum, A. oxyrhynchus*)

### *Background*

Sturgeon were not initially on the list of priority species for this Program, but were added in 1998 after two companies began work on sturgeon aquaculture in New Brunswick. Supreme Sturgeon and Caviar Ltd. (SSC) was based at the Huntsman Marine Science Centre (HMSC; in collaboration with W. Hogans). Canadian Caviar Co. (CCC) was based at the former DFO Saint John (Loch Lomond) salmon hatchery, with collaborative research by M. Litvak at the University of New Brunswick at Saint John (UNBSJ). Two native species were being studied: the shortnose sturgeon (*Acipenser brevirostrum*) and the Atlantic sturgeon (*A. oxyrhynchus*). The main goal of shortnose sturgeon aquaculture is caviar production, but meat may also be marketed. It is expected that mature, caviar-producing shortnose sturgeon can be raised in 4-5 years after hatching under culture conditions. Atlantic sturgeon may be preferred for meat production, since it is faster growing, but matures at a larger size and later age.

### *Research supported by the New Finfish Aquaculture Species Development Program*

Funding was provided to both the SSC and CCC operations in 1999-2000.

**Broodstock**

CCC collected Atlantic sturgeon broodstock from the gillnet fishery in the St. John River in summer 1998 and 1999. Atlantic sturgeon broodstock are large fish, up to 80 kg. Twelve broodstock were collected in 1998, but 6 died within 1 month of capture, and another died later. Fifteen broodstock were collected in 1999; of these, two died shortly after transfer and three others were sacrificed during spawning.

CCC collected shortnose sturgeon broodstock from the St. John River in spring 1998 and 1999. Sixty were collected in 1998 and 30 in 1999. SSC also collected shortnose sturgeon broodstock from the St. John River.

The numbers of sturgeon broodstock being kept at both facilities in November 1999 are shown in the following table.

| *Species* | *Broodstock facility* | *Approximate numbers of broodstock (November 1999)* |
|---|---|---|
| Atlantic sturgeon | CCC | 15 |
| Shortnose sturgeon | CCC | 85 |
| Shortnose sturgeon | SSC | 30 |

At both facilities, shortnose sturgeon successfully spawned when injected with LHRH (luteinizing hormone-releasing hormone). Spawning of Atlantic sturgeon was less successful. LHRH injection did not result in successful spawning of female Atlantic sturgeon broodstock at CCC in 1999; all 6 females injected had atretic (reabsorbed) eggs. Of 3 female Atlantic sturgeon broodstock injected with carp pituitary extract in 1999, one produced mature eggs that were successfully fertilized, but the other two had apparently immature eggs. The results indicated the need for egg biopsies to assess the maturity of eggs prior to broodstock selection, as well as the need to identify environmental cues necessary for final ripening of eggs of Atlantic sturgeon.

An experiment in 1999 by CCC examined the use of photothermal manipulation to shift the period of spawning of shortnose sturgeon. Because of the small numbers of spawning fish, the results were inconclusive, but indicated that 1 month advanced spawning is feasible. Attempts to delay spawning by 2 months resulted in the production of eggs and sperm, but no eggs hatched; however, factors other than the photothermal regime may have been responsible for the lack of hatched eggs. A study at SSC was unable to demonstrate evidence of multiple annual spawning in shortnose sturgeon, but further research was proposed.

Initial attempts by CCC to produce hybrid Atlantic/shortnose sturgeon were unsuccessful (no eggs hatched). Hybridization may result in fish with the higher growth rate of Atlantic sturgeon and earlier maturation of shortnose sturgeon. Also, hybrids would not be subject to the same U.S. import restrictions that are placed on Atlantic and shortnose sturgeon.

**Early rearing and growout**

Both operations produced juvenile shortnose sturgeon, while juvenile Atlantic sturgeon were produced only at CCC. Both operations started with flow-through systems, with various tank types and sizes. SSC later implemented a warmwater recirculation system. Both facilities suffered mortalities due to operational problems. CCC lost some of its 1997 year-class of Atlantic sturgeon as a result of biofilter problems at UNBSJ. CCC also lost several thousand 1999 year-class juveniles (of both species) due to flooding and poor water quality (silt runoff) at the Saint John hatchery in 1999. SSC lost most of its 1999

year-class production of shortnose sturgeon due to chlorine problems at the HMSC facility in June 1999. Both facilities also lost fish due to disease problems (see below). The approximate numbers of each year-class being held in November 1999 are shown in the following table.

| | | *Numbers of each year-class held in November 1999* | | |
|---|---|---|---|---|
| *Species* | *Facility* | *1997* | *1998* | *1999* |
| Atlantic sturgeon | CCC | 7 | 0 | 2,100 |
| Shortnose sturgeon | CCC | - | 3,900 | 3,500 |
| Shortnose sturgeon | SSC | 2,000 | 10,000 | 500 |

Poor tank design and the stress of moving from hatching tanks to larval rearing tanks were thought to have contributed to low larval survival at CCC. A combined hatching and larval rearing tank prototype was constructed. Using this tank, the mortality of shortnose sturgeon larvae after 30 days was reduced from 27.1% in 1998 to 3.2% in 1999.

Growth of juvenile shortnose sturgeon at CCC was found to be significantly higher at 19°C, compared to 8°C. A similar experiment at SSC found higher growth at 18-19°C, compared to 14-15°C. Growth rates at the higher temperatures at the 2 sites were comparable, and indicated that temperatures should be 18°C or higher for a viable commercial rearing system. At such temperatures, flow-through systems are too expensive to operate in Atlantic Canada, due to the costs of heating the water. This means that recirculation systems would be required for optimum growth rates. Research at SSC suggested that the most acceptable recirculating biofilter system for sturgeon culture would be based on low-head floating media biofilters (for nitrification) and pressurized bead filters (for suspended solids removal). More research is required on recirculation technology, including ammonia production within recirculation systems and the ammonia tolerance of sturgeon.

Studies at SSC showed that stocking density affected the growth rate of shortnose sturgeon, primarily due to competition for food at higher densities. Immature shortnose sturgeon (400-2,000 g) grew faster in densities less than 50 kg/m$^3$ than at higher densities. However, acceptable growth was obtained at densities as high as 60-65 kg/m$^3$.

Wild shortnose sturgeon mature at about 3.5 kg. At SSC, cultured sturgeon could reach 600 g in 18 months (from egg stage) and 1.4 kg in 30 months. Some of the 1997 year-class shortnose sturgeon were approaching 2.5 kg in March 2000, but showed no conclusive evidence of gonadal maturity. However, these fish should reach a size required for maturity and caviar production in 2000 (in their 3$^{rd}$ year). Fish from the 1998 year-class had not shown any signs of developing reproductive capacity by March 2000.

There is a need to develop non-invasive, inexpensive methods for determining the gender of immature fish of both species. This is required in order to separate females, which would be kept for caviar production.

Related research (not supported by the Program) has been conducted on both species at UNBSJ (led by M.Litvak). Research topics have included: motility and longevity of sperm; effects of temperature on early larval development; oxygen consumption and ammonia excretion rates of juveniles; and the influence of feeding frequencies on juvenile growth.

**Nutrition**

Recently captured Atlantic sturgeon would not feed. CCC tried a variety of fish, shellfish, dry pellets, and semi-moist pellets as broodstock diets for Atlantic sturgeon. Of the 6 fish collected in 1998, none

were observed to feed in the first year of captivity, after which 3 started feeding on semi-moist pellets. Two of the remaining fish had still not fed by October 1999 and the other fish had died from starvation.

Sturgeon of both species were initially fed live *Artemia*. A study by CCC compared growth and survival of shortnose sturgeon larvae fed on live versus frozen *Artemia*. Survival did not differ between the two diets, but growth was significantly higher with live *Artemia*. The results indicated that frozen *Artemia* cannot be used as a permanent substitute for live *Artemia*, but can be used on a temporary basis if supplies of live *Artemia* are interrupted. CCC began an experiment in 1999 comparing growth of Atlantic sturgeon larvae fed enriched and unenriched *Artemia* (results not yet reported).

Shortnose sturgeon can be weaned onto dry, formulated feed at around 30-40 days post-hatch. In a 1999 trial, SSC reared some shortnose sturgeon larvae using only commercially-prepared larval diets (eliminating the use of live *Artemia*). Compared to 1998, when live *Artemia* were used, survival after 40 days was similar between the years, but growth in 1999 was lower than in 1998. Further trials are planned.

SSC found that juvenile shortnose sturgeon (400-2,500 g) had extremely good feed conversion rates (approximately 0.8) using commercially available diets. The efficacy of commercially available diets on Atlantic sturgeon growth and survival still needs to be determined.

**Fish Health**

All of the Atlantic sturgeon broodstock collected by CCC in 1998 contracted columnaris (a bacterial disease) or fungal infections secondary to the stress of collection and transport. In 1999, recently caught Atlantic sturgeon broodstock were given various prophylactic treatments. Results of this short-term trial suggested that a combination of salt treatment and oxytetracycline injection was effective in reducing infections in recently handled fish. Transportation methods must be improved to reduce stress and mortality of wild caught broodstock.

CCC lost 74% of its 1997 year-class juvenile Atlantic sturgeon at UNBSJ in April 1999: this was attributed to an *E. coli* infection. The remaining Atlantic sturgeon juveniles were successfully treated with oxytetracycline injections. CCC lost its 1998 year-class of Atlantic sturgeon at the Saint John hatchery in August 1998, due to a columnaris infection.

In October-November 1999, epidermal skin lesions were found in one tank of shortnose sturgeon at SSC. The cause of this infection is so far unknown. Treatment involved salt baths, lower temperatures, and reduced densities.

***Summary of Major Accomplishments and Future Research Priorities***

Wild broodstock of both species were collected and maintained. Shortnose sturgeon were successfully spawned after hormone injection. Spawning of Atlantic sturgeon was less successful. Photothermal manipulation of shortnose sturgeon broodstock was initiated. Juveniles of both species were produced, but considerable losses occurred due to disease and operational problems. Growth of shortnose sturgeon was best at warm temperatures, indicating that heated recirculation systems would be required for optimum growth. Growth rates obtained for cultured shortnose sturgeon indicated that they should reach mature size in their 3rd year.

The New Brunswick Department of Agriculture, Fisheries, and Aquaculture indicated the following research priorities for 2000-2005:

*Hatchery techniques*

- Develop a standard hatchery protocol to increase survival and growth rates and decrease costs.

*Sex determination*

- This would reduce costs and increase profits by allowing aquaculturists to selectively rear caviar-producing females.

*Broodstock program*

- Develop faster growing strains of sturgeon and determine care requirements (e.g. nutrition).

*Diet and feeding strategies*

- Develop diets (e.g. artificial diets, microdiets) and assess of feeding strategies at early rearing stages.

*Recirculation systems*

- Determine optimal recirculation technology for rearing sturgeon.

*Fish health*

- Disease prevention, identification and treatment.

## NUTRITION RESEARCH (GENERAL)

Nutrition research examined nutritional requirements and developed diets for rearing of the species in the Program. Considerable research has been conducted to develop and improve diets for salmonids, but relatively little work had been done for the new species. Nutrition research specific to each species has been reported in the previous sections.

New species generally require live feeds in the initial stages following yolk sac absorption. A workshop was held at St. Andrews in September 1998 on the use of live feeds in larval fish culture (Castell and Henry 1998). The focus of the workshop was on live feed preparation and husbandry practices which would minimize bacterial and organic matter contamination, while maximizing the nutritional value of the live feeds. As part of that workshop, Castell et al. (1998) summarized current knowledge on the nutritional value of live feeds used in marine fish culture (algae, rotifers, *Artemia*, live zooplankton), as well as factors affecting their nutritional value.

Nutrition research sponsored by the Program included analytical research on various live feeds (wild and cultured) and the effectiveness of enrichment diets for live feeds. DFO, in collaboration with Maritime Mariculture Inc. (MMI) and Sambro Fisheries Ltd., found that both exposure time and enrichment media had strong influences on the total lipid content and essential fatty acid composition of *Artemia* (Blair et al. 1998a,b). Comparisons were made of larval fish survival and growth when using different enrichment diets (Blair et al. 1998a). Research was also conducted on the development of artificial feeds for the various life stages of each species, including comparisons of various protein sources and feed attractants.

J. Castell (DFO) compared trochophores of quahaugs (*Mercenaria mercenaria*), blue mussels (*Mytilus edulis*), and surf clams (*Spisula solidissima*) produced at the NBDFA Aquarium and Marine Centre (AMC). Mussels were the easiest to produce and contained the highest levels of the highly unsaturated fatty acids (HUFAs) considered essential for larval fish. However, all 3 trochophore species had HUFA levels higher than with the best enrichment of *Artemia* and as good as most enriched rotifers. These results suggested that trochophores of any of these species should satisfy the essential fatty acid requirements of marine fish larvae. It was also found that the total lipid and essential fatty acid content of the trochophores could be enhanced by alterations in holding and feeding conditions of the broodstock molluscs. In other research, Litvak (1996, 1999) found that rotifers and *Artemia* were necessary for best growth and survival of winter flounder larvae, but trochophores did not appear to be beneficial as a diet

component. Work on the cryopreservation of sea scallop (*Placopecten magellanicus*) embryos and larvae was conducted by Atlantic Low Temperature Storage (O. Kukal), for potential use in marine fish aquaculture.

D. Nanton (Dalhousie University) and J. Castell (DFO) examined the potential use of harpacticoid copepods (*Tisbe* sp., *Amonardia* sp.) as live feed for larval culture of marine finfish. Research was conducted on the effects of various algal diets and baker's yeast on the fatty acid composition and nutritional value of harpacticoid copepods (Nanton, M.Sc. thesis 1997; Nanton and Castell 1998a,b; Nanton et al. 1996). *Tisbe* sp. and *Amonardia* sp. were found to have higher DHA (docosahexaenoic acid) to EPA (eicosapentaenoic acid) ratios than did wild zooplankton or mussel larvae, indicating high potential as live feeds for larval fish culture (Nanton and Castell 1999). Harpacticoid copepods have the advantages of tolerance to wide ranges of environmental conditions, the ability to utilize different food sources, short life cycles, high reproductive capacities, and they can be raised at high densities. A disadvantage is that they tend to stay on the walls and bottom of culture tanks, so they may be less available to fish larvae in the water column.

Further research is required on diets and nutrition of all stages of the priority species, especially on the development of artificial diets to replace live feeds which are currently required for first feeding.

## FISH HEALTH RESEARCH (GENERAL)

Fish health investigations were led by the Research and Productivity Council (RPC; research led by S. Griffiths), with the Atlantic Veterinary College (AVC), the National Research Council Institute for Marine Biosciences (NRC-IMB), DFO, and the various culture facilities. Refer to the previous sections on each species for fish health research specific to those species.

At the start of this Program, very little was known about fish health of the priority species. Considerable knowledge has been gained concerning pathogenic bacteria, viruses, and other organisms in these species under culture conditions. In addition, work was undertaken to develop disease monitoring, surveillance, control, and diagnostic protocols with respect to new finfish species culture.

The main fish health work undertaken was the provision of monitoring and diagnostic services for the research and culture facilities within the Program. This involved regular monitoring of culture water, algae, live feeds, fish larvae, juveniles, and broodstock at the various facilities, as well as investigations into the causes of mortalities. The biggest problem in the culture of new species is the high mortalities in the early life stages. Emphasis was on bacteriology, since evidence indicated that bacteria were involved in larval crashes. Some viral activity was observed in moribund juveniles, but no pathology was attributable to the viral presence.

Research was also conducted on improving diagnostic methods for fish health problems of cultured finfish. RPC conducted work to establish cell lines to permit characterization of viruses in new cultured finfish species. RPC also developed an innovative DNA profiling technique for rapid analysis of bacterial loading in samples from hatcheries. This method involved DNA profiling by polymerase chain reaction (PCR) amplification of bacterial 16S ribosomal DNA sequences, followed by denaturing gradient gel electrophoresis (PCR-DGGE) to identify predominant bacterial species as represented by individual DNA bands within the profile (Griffiths et al. 1998).

Algal cultures were frequently prone to bacterial contamination. These bacteria did not appear to be associated with larval mortalities, but may affect the growth and quality of the algae.

Live feeds used in larval culture (rotifers, *Artemia*, zooplankton) were found to be associated with high levels of bacterial activity, indicating the need for decontamination of live feeds. *Vibrio alginolyticus* was found to be dominant in rotifer and *Artemia* cultures at Maritime Mariculture Inc. (MMI) and the NBDFA Aquarium and Marine Centre (AMC). Three *Vibrio* species (not *V. alginolyticus*) were found on *Artemia* at R&R Finfish Development Ltd. (R&R). It appears that live feed products are not sterile, but are arriving at the hatcheries carrying bacteria. There was, however, no evidence that the predominant species found in live feeds were associated with larval mortalities.

Trials at R&R in 1998 found that the most effective means of reducing bacterial loading in enriched *Artemia* was by rinsing with fresh water, although the effect varied with the enrichment medium used. RPC found that the dominant bacterial species on rotifers and *Artemia* at MMI and AMC could not be removed from by rinsing. Preliminary trials on the use of disinfectants such as *Pyceze*™ (active ingredient bronopol) at AMC and *Hatch Control*™ at MMI found that they were effective at reducing bacterial contamination of live *Artemia* by 2-3 orders of magnitude.

Bacteria were found to be associated with most larval and juvenile mortality events (see previous sections on each species). Antibiotic treatments were successfully used to manage some of these bacterial problems.

Fish were analyzed for the presence of diseases, such as infectious salmon anemia (ISA). There was no strong evidence that the ISA virus occurred pathogenically in any of the cultured species. However, because ISA virus is believed to be able to survive (but not replicate) in the mucous layer covering fish, strict precautions are recommended when considering introductions and transfers of these species to or from areas where ISA is present.

In summary, fish health problems were diagnosed and progress was made in reducing mortalities at various life stages of each species. However, further reductions in mortality rates in early stages are required if commercialization of these species is to be successful. Further research is required on disease diagnosis, prevention, and treatment.

**APPENDIX 1**

## LIST OF PUBLICATIONS

The following is a list of publications reporting on research and development projects that received financial support from the New Finfish Aquaculture Species Development Program. Also included – indicated with an asterisk (*) – are publications which are referred to in the text, but which were not funded by this Program.

**Batt, J.** 1998. Winter flounder culture. Bull. Aquacul. Assoc. Canada 98-1: 11-13.

**Blair, T., Batt, J., Melanson, R., Kirk, S., and Castell, J.** 1998a. Evaluation of several commercial enrichment media for enhancing nutritional value of rotifers for winter flounder (*Pleuronectes americanus*). Bull. Aquacul. Assoc. Canada 98-4: 35-37.

**Blair, T., Powell, F., Brooking, P., and Castell, J.** 1998b. Evaluation of commercial enrichment media for enhancing nutritional value of *Artemia* for larval halibut (*Hippoglossus hippoglossus*) culture. Bull. Aquacul. Assoc. Canada 98-4: 21-24.

**Blair, T., Castell, J., Mercer, S., and Powell, F.** 1999. The effect of dietary protein and lipid on juvenile halibut. Bull. Aquacul. Assoc. Canada 99-4: 16-18.

***Brown, J.A. and Keough, T.** 1994. Atlantic halibut. Bull. Aquacul. Assoc. Canada 94-1: 9-12.

***Cairns, D., Robichaud-LeBlanc, K., Bradford, R., Peterson, R.H., and Angus, R.** 1999. Striped bass culture in eastern Canada. Can. Stock Assess. Secretariat Res. Doc. 99/004.

**Castell, J. and Henry, R.** (ed.). 1998. Larval culture–live feed workshop: notes, papers and registration list. Huntsman Marine Science Centre and Fisheries and Oceans Canada, St. Andrews, NB.

**Castell, J.D., Boston, L.D., Nanton, D.A., Blair, T., Douglas, D., Batt, J., and Lanteigne, C.** 1998. Factors affecting nutritional value of live feed organisms for use in larval marine fish culture in Atlantic Canada. *In* Larval culture–live feed workshop: notes, papers and registration list. *Edited by* J. Castell and R. Henry. Huntsman Marine Science Centre and Fisheries and Oceans Canada, St. Andrews, NB. pp. 61-86.

**Cook, R.H. and Watson-Wright, W.** 1995. Marine fish culture initiatives in Atlantic Canada. Int. Counc. Explor. Sea C.M. 1995/F:17.

**Douglas, S.E., Gawlicka, A., Mandla, S., and Gallant, J.W.** 1999. Ontogeny of the stomach in winter flounder: characterization and expression of the pepsinogen and proton pump genes and determination of pepsin activity. J. Fish Biol. 55: 897-915.

**Downing, G. and Litvak, M.K.** 1999a. The influence of light intensity on growth of larval haddock. N. Am. J. Aquaculture 61: 135-140.

**Downing, G. and Litvak, M.K.** 1999b. The effect of photoperiod, tank colour and light intensity on growth of larval haddock. Aquacult. Int. 7: 369-382.

**Downing, G. and Litvak, M.K.** 2001. Influence of spectral composition on first feeding, growth, and survival of larval haddock (*Melanogrammus aeglefinus*). Aquacul. Assoc. Canada Special Publ. 4: 37-40.

## LIST OF PUBLICATIONS

**Duston, J., MacIsaac, P.F., and White, C.E.** 2001. Striped bass, *Morone saxatilis* (Bay of Fundy stock): growth performance in a recirculation system. Aquacul. Assoc. Canada Special Publ. 4: 49-52.

**Ewart, K.V., Blanchard, B., Johnson, S.C., Bailey, W.L., Martin-Robichaud, D.J., and Buzeta, M.I.** 2000. Freeze susceptibility in haddock (*Melanogrammus aeglefinus*). Aquaculture 188: 91-101.

**Fredette, M., Batt, J., and Castell, J.** 2000. Feeding stimulant for juvenile winter flounder. N. Am. J. Aquaculture 62: 157-160.

**Griffiths, S., Melville, K., and Saunders, G.** 1998. Microbial profiling of live feed and algae by DNA analysis. *In* Larval culture–live feed workshop: notes, papers and registration list. *Edited by* J. Castell and R. Henry. Huntsman Marine Science Centre and Fisheries and Oceans Canada, St. Andrews, NB. pp. 88-89.

***Harmon, P. and Peterson, R.** 1994. The effect of temperature and salinity on the growth of striped bass (*Morone saxatilis*). Bull. Aquacul. Assoc. Canada 94-2: 45-47

**Hebb, C.D., Castell, J.D., Anderson, D.M., and Batt, J.** 1997. Nutritional studies on growth and protein utilization during the juvenile stage of winter flounder (*Pleuronectes americanus*). Bull. Aquacul. Assoc. Canada 97-2: 45-47.

***Hendry, C.I., Martin-Robichaud, D.J., and Benfey, T.J.** 2001. Hormonal sex reversal of Atlantic halibut (*Hippoglossus hippoglossus*, L.). Aquacul. Assoc. Canada Special Publ. 4: 41-44.

**Henry, R.** 1997. Overview of recent developments in haddock culture in New Brunswick. Aquacul. Assoc. Canada Special Publ. 2: 37-40.

***Hogans, W.E.** 1997. Growth and survival of cultured striped bass (*Morone saxatilis*) larvae and fry at ambient and elevated freshwater, brackish and marine water temperatures. Aquacul. Assoc. Canada Special Publ. 2: 111.

***Lee, G.W.Y. and Litvak, M.K.** 1996a. Weaning of metamorphosed winter flounder (*Pleuronectes americanus*) reared in the laboratory: comparison of two commercial artificial diets on growth, survival and conversion efficiency. Aquaculture 144: 251-263.

***Lee, G.W.Y. and Litvak, M.K.** 1996b. Weaning of wild young-of-the-year winter flounder *Pleuronectes americanus* (Walbaum) on a dry diet: effects on growth, survival and feed efficiency ratios. J. World Aquacult. Soc. 27: 30-39.

***Litvak, M.K.** 1994. Winter flounder. Bull. Aquacul. Assoc. Canada 94-1: 4-8.

**Litvak, M.** 1996. Development of winter flounder (*Pleuronectes americanus*) for aquaculture: state of the art. Bull. Aquacul. Assoc. Canada 96-3: 24-26.

**Litvak, M.** 1998. The development of haddock culture in Atlantic Canada. Bull. Aquacul. Assoc. Canada 98-1: 30-33.

**Litvak, M.** 1999. The development of winter flounder (*Pleuronectes americanus*) for aquaculture in Atlantic Canada: current status and future prospects. Aquaculture 176: 55-64.

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**Martin-Robichaud, D.J., and Peterson, R.H.** 1998. Effects of light intensity, tank colour and photoperiod on swimbladder inflation success in larval striped bass, *Morone saxatilis* (Walbaum). Aquac. Res. 29: 539-547.

**Martin-Robichaud, D.J. and Rommens, M.A.** 1998. Effects of temperature and salinity on fertilization of halibut (*Hippoglossus hippoglossus* L.) eggs. Bull. Aquacul. Assoc. Canada 98-2: 27-29.

**Martin-Robichaud, D.J. and Rommens, M.** 2000. Fertilization success of Atlantic halibut (*Hippoglossus hippoglossus*) gametes after cold storage. *In* 6th International Symposium on the Reproductive Physiology of Fish, Bergen, Norway, 4-9 July 1999. *Edited by* B. Norberg, O.S. Kjesbu, G.L. Taranger, E. Andersson, and S.O. Stefansson. University of Bergen, Bergen, Norway. p. 427.

**Martin-Robichaud, D.J., Rommens, M.A., and Vallee, L.** 1998a. Sex determination of flatfish and gadids using ultrasonography. Bull. Aquacult. Assoc. Canada 98-3: 19-23.

**Martin-Robichaud, D.J., Rommens, M.A., and Vallee, L.** 1998b. Sex determination of Atlantic halibut (*Hippoglossus hippoglossus*), winter flounder (*Pleuronectes americanus*) and haddock (*Melanogrammus aeglefinus*) using ultrasonography. *In* Fish performance studies. *Edited by* D. MacKinlay, K. Howard, and J. Cech, Jr. American Fisheries Society, Physiology Section. pp. 161-166.

**Martin-Robichaud, D.J., Powell, J., and Wade, J.** 2001. Gonadotropin-releasing hormone affects sperm production of Atlantic halibut (*Hippoglossus hippoglossus*). Aquacul. Assoc. Canada Special Publ. 4: 45-48.

**Morrison, C.M., Waiwood, K., Lanteigne, C., Martell, D.J., O'Neil, D., and Leggiadro, C.** 1997. Normal and abnormal development of haddock larvae and comparison with that of cod. Aquacul. Assoc. Canada Special Publ. 2: 58-60.

**Morrison, C.M., Bird, C., O'Neil, D., Leggiadro, C., Martin-Robichaud, D., Rommens, M., and Waiwood, K.** 1999. Structure of the egg envelope of the haddock, *Melanogrammus aeglefinus*, and effects of microbial colonization during incubation. Can. J. Zool. 77: 890-901.

**Nanton, D.A. and Castell, J.D.** 1998a. Preliminary trials using a harpacticoid copepod, *Tisbe* sp., as a diet for larval haddock and American plaice. Bull. Aquacul. Assoc. Canada 98-4: 38-40.

**Nanton, D.A. and Castell, J.D.** 1998b. The effects of dietary fatty acids on the fatty acid composition of harpacticoid copepod, *Tisbe* sp., for use as a live food for marine fish larvae. Aquaculture 163: 249-259.

**Nanton, D.A. and Castell, J.D.** 1999. The effects of temperature and dietary fatty acids on the fatty acid composition of harpacticoid copepods, for use as a live food for marine fish larvae. Aquaculture 175: 167-181.

**Nanton, D.A., Castell, J.D., and McLaren, I.A.** 1996. Fatty acid composition and nutritional value of a marine harpacticoid copepod, fed various algal diets. Bull. Aquacul. Assoc. Canada 96-1: 38-40.

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***Peterson, R.H.** 1991. Consideration for design of culture facilities for early stages of striped bass (*Morone saxatilis*). Bull. Aquacul. Assoc. Canada 91-3: 86-88.

***Peterson, R.H.** 1994a. American eel. Bull. Aquacul. Assoc. Canada 94-1: 22-23.

***Peterson, R.H.** 1994b. Striped bass. Bull. Aquacul. Assoc. Canada 94-1: 24-28

***Peterson, R.H. and Martin-Robichaud, D.J.** 1994. First feeding and growth of elvers of the American eel (*Anguilla rostrata* (Lesueur) at several temperature regimes. Can. Tech. Rep. Fish. Aquat. Sci. 2013.

**Peterson, R.H., Benfey, T.J., McGeachy, S.A., Rommens, M., Richards, K., and Harmon, P.** 1996a. Sex ratios of eels reared under two temperature regimes. Can. Tech. Rep. Fish. Aquat. Sci. 2135.

***Peterson, R.H., Martin-Robichaud, D.J., and Berge, Å.** 1996b. Influence of temperature and salinity on length and yolk utilization of striped bass larvae. Aquac. Int. 4: 89-103.

**Peterson, R.H., Martin-Robichaud, D.J., and Harmon, P.** 1996c. Striped bass and American eel research. *In* Science Review 1994 & '95 of the Bedford Institute of Oceanography, Gulf Fisheries Centre, Halifax Fisheries Research Laboratory, and the St. Andrews Biological Station. Fisheries and Oceans Canada, Maritimes Region, Dartmouth, NS. pp. 67-70.

**Peterson, R.H., Martin-Robichaud, D.J., Harmon, P., and Berge, Å.** 1996d. Notes on striped bass culture, with reference to the Maritime provinces. Fisheries and Oceans Canada, Communications Branch, Halifax, NS.

**Peterson, R.H., Martin-Robichaud, D.J., Harmon, P., and Berge, Å.** 1997. The striped bass as an aquaculture species: a review. Aquacul. Assoc. Canada Special Publ. 2: 22-24.

**Ramsay, J.M., Castell, J.D., Anderson, D.M., and Hebb, C.D.** 2000. Effects of fecal collection methods on estimation of digestibility of protein feedstuffs by winter flounder. N. Am. J. Aquaculture 62: 168-173.

**Raymond, D.** 1998. Development of Atlantic halibut culture in Canada. Bull. Aquacul. Assoc. Canada 98-1: 14-15.

**Tibbetts, S.M., Lall, S.P., and Anderson, D.M.** 1998. Optimum protein level in a practical fishmeal-based diet for juvenile American eel (*Anguilla rostrata*). Bull. Aquacul. Assoc. Canada 98-2: 50-52.

**Tibbetts, S.M., Lall, S.P., and Anderson, D.M.** 2000. Dietary protein requirement of juvenile American eel (*Anguilla rostrata*) fed practical diets. Aquaculture 186: 145-155.

**Trippel, E.A., Doherty, C.M., Wade, J., and Harmon, P.R.** 1998. Controlled breeding technology for haddock (*Melanogrammus aeglefinus*) in mated pairs. Bull. Aquacul. Assoc. Canada 98-3: 30-35.

**Trippel, E.A., Castell, J.D., Neil, S.R.E., and Blair, T.J.** 2000. Assessment of egg quality of haddock (*Melanogrammus aeglefinus*) in paired matings. *In* 6th International Symposium on the Reproductive Physiology of Fish, Bergen, Norway, 4-9 July 1999. *Edited by* B. Norberg, O.S.

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Kjesbu, G.L. Taranger, E. Andersson, and S.O. Stefansson. University of Bergen, Bergen, Norway. pp. 405-407.

***Waiwood, K.G.** 1994. Haddock. Bull. Aquacul. Assoc. Canada 94-1: 16-21.

***Waiwood, K.G., Howes, K.G., and Reid, J.** 1994. Halibut aquaculture research at the St. Andrews Biological Station. *In* Science Review 1992 & '93 of the Bedford Institute of Oceanography, the Halifax Fisheries Research Laboratory, and the St. Andrews Biological Station. Fisheries and Oceans Canada, Dartmouth, NS. pp. 43-46.

**Waiwood, K.G., Reid, J., and Howes, K.** 1997. Canadian perspective on halibut culture. Aquacul. Assoc. Canada Special Publ. 2: 43-45.

### *Theses*

**Casey, P.C.** 2000. Effects of photoperiod and temperature on growth and survival of young-of-the-year laboratory reared winter flounder (*Pleuronectes americanus*) juveniles. M.Sc. thesis, University of New Brunswick, Saint John, NB.

**Downing, G.** 2001. The impact of lighting conditions on growth and development of larval haddock (*Melanogrammus aeglefinus*) in culture. Ph.D. thesis, University of New Brunswick, Saint John, NB.

**Hebb, C.D.** 1998. Nutritional studies on protein utilization by juvenile winter flounder (*Pleuronectes americanus*) and haddock (*Melanogrammus aeglefinus*). M.Sc. thesis, Nova Scotia Agricultural College, Truro, NS and Dalhousie University, Halifax, NS.

**Nanton, D.A.** 1997. Nutritional value of marine harpacticoid copepods as live food for marine fish larvae. M.Sc. thesis, Dalhousie University, Halifax, NS.

**Tibbetts, S.M.** 1999. Dietary protein and energy utilization by juvenile American eel (*Anguilla rostrata*). M.Sc. thesis, Nova Scotia Agricultural College, Truro, NS.

**White, C.E.** 2001. The influence of light intensity and turbidity on prey capture and phototactic behaviour of larval and early juvenile stages of striped bass (*Morone saxatilis*). M.Sc. thesis, Nova Scotia Agricultural College, Truro, NS.

## LIST OF CONFERENCE PRESENTATIONS

The following is a list of conference presentations which reported on research and development projects that received financial support from the New Finfish Aquaculture Species Development Program.

***Coldwater Aquaculture to the Year 2000***
Huntsman Marine Science Centre Symposium
St. Andrews, NB, 6-8 September 1995

- **Henry, R.** Developments in haddock culture in New Brunswick. (published as Henry 1997)
- **Martin-Robichaud, D.J. and Peterson, R.H.** Factors affecting swimbladder inflation success in larval striped bass. (published as Martin-Robichaud and Peterson 1998)
- **Morrison, C.M., Waiwood, K.G., Lanteigne, C., Martell, D.J., O'Neil, D., and Leggiadro, C.** Early normal and abnormal development of haddock larvae and comparison with that of cod. (published as Morrison et al. 1997)
- **Peterson, R.H., Martin-Robichaud, D.J., Harmon, P., and Berge, Å.** An overview of striped bass culture. (published as Peterson et al. 1997)
- **Waiwood, K.G., Reid, J., and Howes, K.** Canadian perspective on halibut culture. (published as Waiwood et al. 1997)

***Canadian Conference for Fisheries Research 1996***
Montreal, QC, 4-6 January 1996

- **Benfey, T.J., Peterson, R.H., and Martin-Robichaud, D.J.** Use of all-female stocks of fish for aquaculture.
- **Downing, G. and Litvak, M.K.** Growth and survival of larval haddock under different light intensities.
- **Litvak, M.K.** Recent advances in the development of new species for aquaculture: what makes the ideal candidate?

***6th Annual Atlantic Universities Aquaculture Conference***
Atlantic Provinces Council on the Sciences (APICS)
University of New Brunswick, Fredericton, NB, 8-10 March 1996

- **Downing, G. and Litvak, M.K.** Do you see what I see? How does light intensity influence the growth of larval winter flounder and haddock?
- **Litvak, M.K.** Development of new species for aquaculture: What makes an ideal candidate?

***Aquaculture Canada '96***
13th annual meeting of the Aquaculture Association of Canada
Ottawa, ON, 2-5 June 1996

- **Litvak, M.K.** Development of winter flounder (*Pleuronectes americanus*) for aquaculture: State of the art. (published as Litvak 1996)

***9th Atlantic Aquaculture Exposition, Conference and Fair***
Technical Sessions: Opportunities through diversification
St. Andrews, NB, 20 June 1996

- **Batt, J.** New species development - entrance by existing companies.
- **Litvak, M.K.** Development of haddock for aquaculture in Atlantic Canada.
- **Litvak, M.K.** Development of winter flounder for aquaculture in Atlantic Canada.
- **Raymond, D. and Rabben, H.** The economic viability of halibut culture in Maritime Canada.

## LIST OF CONFERENCE PRESENTATIONS

***Canadian Conference for Fisheries Research 1997***
Ottawa, ON, 2-4 January 1997
- **Downing, G. and Litvak, M.K.** From start to finfish: shedding light on the culture of larval haddock (*Melanogrammus aeglefinus*). (poster)

***World Aquaculture '97***
Annual international conference & exposition of the World Aquaculture Society
Seattle, WA, USA, 19-23 February 1997
- **Downing, G. and Litvak, M.K.** From start to finfish: shedding light on the culture of larval haddock (*Melanogrammus aeglefinus*). (poster)

***7th Annual Atlantic Universities Aquaculture Conference***
Atlantic Provinces Council on the Sciences (APICS)
Nova Scotia Agricultural College, Truro, NS, 7-9 March 1997
- **Casey, P.C. and Litvak, M.K.** Effect of photoperiod on growth of juvenile winter flounder.
- **Hebb, C., Castell, J.D., and Anderson, D.M.** Nutritional studies on growth and protein utilization during the juvenile stage of winter flounder (*Pleuronectes americanus*).
- **Morrison, C.M., Waiwood, K., Lanteigne, C., O'Neil, D., and Leggiadro, C.** Normal and abnormal development of haddock larvae.
- **Tibbetts, S.M., Lall, S.P., and Anderson, D.M.** Feed enhancement and diet development for juvenile stage American eel (*Anguilla rostrata*).

***Aquaculture Canada '97***
14th annual meeting of the Aquaculture Association of Canada
Quebec City, QC, 10-13 June 1997
- **Batt, J.** Winter flounder culture. (published as Batt 1998)
- **Casey, P.C. and Litvak, M.K.** Effect of photoperiod on growth of juvenile winter flounder.
- **Hebb, C.D., Castell, J.D., Anderson, D.M., and Batt, J.** Nutritional studies on growth and protein utilization during the juvenile stage of winter flounder (*Pleuronectes americanus*). (poster; published as Hebb et al. 1997)
- **Litvak, M.K.** Haddock culture. (published as Litvak 1998)
- **Martin-Robichaud, D.J. and Peterson, R.H.** Effects of light intensity, tank colour and photoperiod on swimbladder inflation success in larval striped bass (*Morone saxatilis*).
- **Morrison, C.M., Waiwood, K., Lanteigne, C., O'Neil, D., and Leggiadro, C.** Normal and abnormal development of haddock larvae. (poster)
- **Raymond, D., Rabben, H., and Powell, F.** Atlantic halibut commercialization in Canada. (published as Raymond 1998)
- **Rommens, M., Martin-Robichaud, D.J., and Howes, K.** Marine finfish broodstock care at the St. Andrews Biological Station.
- **Watson-Wright, W.M. and Chang, B.D.** New marine finfish aquaculture species research in Atlantic Canada.

## LIST OF CONFERENCE PRESENTATIONS

***Aquaculture '98***
Annual international conference & exposition of the World Aquaculture Society
Las Vegas, NV, USA, 15-19 February 1998

- **Litvak, M.K.** The development of winter flounder *Pleuronectes americanus* for aquaculture in Atlantic Canada: current status and future prospects.
- **Tibbetts, S.M., Lall, S.P., and Anderson, D.M.** Optimum dietary protein requirement for juvenile American eel ( *Anguilla rostrata*). (poster)

***8th Annual Atlantic Universities Aquaculture Conference***
Atlantic Provinces Council on the Sciences (APICS)
Dalhousie University, Halifax, NS, 6-8 March 1998

- **Downing, G. and Litvak, M.K.** The influence of light on the embryonic development and hatching of larval haddock and winter flounder.
- **Hebb, C., Anderson, D., and Castell, J.** Apparent digestibility of alternate protein sources in diets for winter flounder (*Pleuronectes americanus*).
- **Tibbetts, S.M., Lall, S.P., Anderson, D.M., and Peterson, R.H.** Nutritional development for juvenile American eel (*Anguilla rostrata*).
- **Vallee, L., Martin-Robichaud, D.J., Rommens, M.A., and Benfey, T.J.** Ultrasonography as a non-invasive method of sex determination in juvenile halibut (*Hippoglossus hippoglossus*).

***Aquaculture Canada '98***
15th annual meeting of the Aquaculture Association of Canada
St. John's, NF, 31 May-3 June 1998

- **Batt, J., Melanson, R., Kirk, S., Castell, J., and Blair, T.** Evaluations of several commercial enrichment media for enhancing nutritional value of rotifers for winter flounder (*Pleuronectes americanus*). (published as Blair et al. 1998a)
- **Hebb, C., Anderson, D.M., and Castell, J.D.** Apparent digestibility of plant proteins in diets for winter flounder (*Pleuronectes americanus*).
- **Hominick, C.P. and Duston J.** *Artemia* as feed for Bay of Fundy larval striped bass: is HUFA enrichment necessary?
- **Lanteigne, C., Castell, J.D., and Blair, T.** The potential use of trochophores from several local molluscs as live food for larval marine fish culture: Total lipid and fatty acid composition.
- **Martin-Robichaud, D.J., Rommens, M.A., and Vallee, L.** Sex determination of winter flounder (*Pleuronectes americanus*), Atlantic halibut (*Hippoglossus hippoglossus*) and haddock (*Melanogrammus aeglefinus*) using ultrasonography. (published as Martin-Robichaud et al. 1998a)
- **Nanton, D. and Castell, J.** Nutritional value of marine harpacticoid copepods as live food for marine fish larvae. (published as Nanton and Castell 1998a)
- **Powell, F., Brooking, P., Castell, J., and Blair, T.** Effects of concentration and exposure time of commercial enrichment media on lipids of *Artemia* nauplii: Implications for use in culture of larval Atlantic halibut (*Hippoglossus hippoglossus* L.). (published as Blair et al. 1998b)
- **Rioux, P.** Overview of the 1998 research activities at the Aquarium and Marine Center.
- **Tibbetts, S.M., Lall, S.P., and Anderson, D.M.** Optimum protein level in a practical fish-meal based diet for juvenile American eel (*Anguilla rostrata*). (published as Tibbetts et al. 1998)
- **Trippel, E.A., Doherty, C.M., Wade, J., and Harmon, P.R.** Maternal and paternal reproductive characteristics of spawning haddock (*Melanogrammus aeglefinus*) in mated pairs. (published as Trippel et al. 1998)

## LIST OF CONFERENCE PRESENTATIONS

***8th International Symposium on Microbial Ecology***
International Society for Microbial Ecology
Halifax, NS, 9-14 August 1998
- **Melville, K. and Griffiths, S.** Profiling of bacterial species associated with haddock larval mortality by PCR amplification of 16S rDNA and denaturing gradient gel electrophoresis.

***Larval Culture Live Feed Workshop***
St. Andrews, NB, 22-24 September 1998
Notes and papers published in Castell and Henry (1998)
- **Castell, J.** Review of factors affecting nutrient composition of live feeds (algae, rotifers, Artemia, mollusc trochophores, wild zooplankton and cultured copepods). (published as Castell et al. 1998)
- **Griffiths, S.** Summary and discussion of water quality assessments in larval rearing systems 1997, 1998. (published as Griffiths et al. 1998)

***Rendez-vous BioAtlantech 1999***
Fredericton, NB, 27-30 July 1999
- **Brown, N.** Application of intensive culture techniques to Atlantic halibut farming in the Maritimes.
- **Griffiths, S.** Diagnostic testing and microbial profiling in finfish aquaculture.

***Aquaculture Canada '99***
16th annual meeting of the Aquaculture Association of Canada
Victoria, BC, 26-29 October 1999
- **Blair, T.J., Castell, J.D., Mercer, S., Lall, S.P., and Powell, F.** The effect of different dietary protein and lipid levels on juvenile halibut (*Hippoglossus hippoglossus* L.). (published as Blair et al. 1999) (*Melanogrammus aeglefinus*)
- **Casey, P.C. and Litvak, M.K.** Do winter flounder (*Pleuronectes americanus*) grow fast enough? Effect of temperature on growth of young of the year juveniles.
- **Castell, J.D., Blair, T.J., Mercer, S., Trippel, E.A., Madsen, K., Neil, S., Martin-Robichaud, D., and Wade, J.** Consideration of egg quality factors from individual pairs and communal spawning haddock, *Melanogrammus aeglefinus*.
- **Johnson, S.C., Blanchard, B.C., Lanteigne, C., Lall, S., and Frantsi, C.** Development of haddock (*Melanogrammus aeglefinus*) aquaculture in Atlantic Canada.

***Canadian Conference for Fisheries Research 2000***
Fredericton, NB, 6-8 January 2000
- **Puvanendran, V. and Allen, J.H.** Huntsman scientific program on flounder aquaculture. (poster)
- **Trippel, E.A., Reid, J., Howes, K., Neil, S., Madsen, K., Taylor, T., Harmon, P., Castell, J., Blair, T., Martin-Robichaud, D., Wade, J., and Aiken, D.** Haddock aquaculture – a systems approach to the development of new species.

***10th Annual Atlantic Universities Aquaculture Conference***
Atlantic Provinces Council on the Sciences (APICS)
Mount Allison University, Sackville, NB, 10-12 March 2000
- **Nanton, D.A., Lall, S.P., and McNiven, M.A.** Effects of dietary lipid on fatty acid liver condition and lipid transport in juvenile haddock, *Melanogrammus aeglefinus*.

## LIST OF CONFERENCE PRESENTATIONS

***Aquaculture Canada 2000***
17th annual meeting of the Aquaculture Association of Canada
Moncton, NB, 28-31 May 2000

- **Brown, N.P.** Progress in Atlantic halibut farming in the Maritimes.
- **Downing, G. and Litvak, M.K.** Influence of spectral composition on first feeding, growth, and survival of larval haddock (*Melanogrammus aeglefinus*). (published as Downing and Litvak 2001)
- **Duston, J., MacIsaac, P.F., and White, C.E.** Striped bass (Bay of Fundy stock): growth performance in a recirculation system. (poster; published as Duston et al. 2001)
- **Johnson, S.C., van der Meer, D.J., Leggiadro, C.T., Leadbeater, S.A., Melanson, R.J., and Lall, S.P.** The effects of different feeding regimes on haddock (*Melanogrammus aeglefinus*) larval development and survival.
- **Litvak, M.K.** The development of winter flounder (*Pseudopleuronectes americanus*) for aquaculture: rumors, myths, and reality.
- **Martin-Robichaud, D.J., Powell, J., and Wade, J.** Gonadotropin-releasing hormone affects sperm production of Atlantic halibut (*Hippoglossus hippoglossus*). (published as Martin-Robichaud et al. 2001)
- **Roy, P.K. and Lall, S.P.** Phosphorus nutrition of haddock (*Melanogrammus aeglefinus*): quantitative requirement, deficiency signs and waste output.
- **Tibbetts, S.M., Lall, S.P., and Milley, J.E.** Utilization of major dietary nutrients by juvenile haddock (*Melanogrammus aeglefinus*).

***11th Annual Atlantic Universities Aquaculture Conference***
Atlantic Provinces Council on the Sciences (APICS)
Mount Saint Vincent University, Halifax, NS, 9-11 March 2001

- **Nanton, D.A., Lall, S.P., Dolphin, P.J., and McNiven, M.A.** Plasma lipoproteins in juvenile haddock (*Melanogrammus aeglefinus*).
- **Roy, P.K., Lall, S.P., and Hall, B.K.** Role of phosphorus in haddock (*Melanogrammus aeglefinus*).

***Aquaculture Canada 2001***
18th annual meeting of the Aquaculture Association of Canada
Halifax, NS, 6-9 May 2001

- **Frantsi, C., Lanteigne, C., Blanchard, B., Alderson, R., Lall, S., Johnson, S., , Leadbeater, S., Martin-Robichaud, D., and Rose, P.** Haddock *Melanogrammus aeglefinus* culture in Atlantic Canada.
- **Griffiths, S., Cook, M., Vincent, S., St. Pierre, M., and Lanteigne, C.** Profiling of bacterial species associated with haddock larviculture by PCR amplification of 16S rDNA and denaturing gradient gel electrophoresis (PCR-DGGE). (poster)
- **Nanton, D.A., Lall, S.P., Dolphin, P.J., and McNiven, M.A.** Plasma lipoproteins in juvenile haddock (*Melanogrammus aeglefinus*).
- **Raymond, D., Powell, F., and Warrington, S.** Advances in Atlantic halibut aquaculture in the Bay of Fundy.
- **Tibbetts, S.M., Lall, S.P., and Milley, J.E.** Effect of dietary protein/energy ration on growth, nutrient utilization and hepatosomatic index of juvenile haddock, *Melanogrammus aeglefinus*.
- **White, C.E. and Duston, J.** Ontogenetic change in effects of light intensity and turbidity on prey capture by larval striped bass.

**APPENDIX 3**



## STEERING COMMITTEE MEMBERS (1994-2000)

### *Co-Chairs:*

*For the New Brunswick Department of Fisheries and Aquaculture (Fredericton, NB):*
David MacMinn 1994-1998; John Kershaw 1998-1999; Kim Lipsett 1999-2000
*For Fisheries and Oceans Canada (St. Andrews, NB):*
Wendy Watson-Wright 1994-1997; David Aiken 1997-2000

### *Subcommittee Chairs:*

*Broodstock:*
Hugh Madill (New Brunswick Department of Fisheries and Aquaculture, St. George, NB) 1994-2000
*Early Rearing:*
Chris Frantsi (Connors Bros. Ltd., Blacks Harbour, NB) 1994-2000
*Nutrition:*
Keith Were (Moore-Clark Canada, St. Andrews, NB) 1994-2000
*Fish Health:*
Bev Bacon (Research and Productivity Council, Fredericton, NB) 1994-2000
*Engineering and Technology:*
Will Apold (Tavel Ltd., Dartmouth, NS) 1995-1997
*Planning and Administration:*
Michel Thériault 1994-1995, Maurice Bernier 1995-2000 (New Brunswick Department of Fisheries and Aquaculture, Fredericton, NB)

### *Members:*

John Allen (Huntsman Marine Science Centre, St. Andrews, NB) 1994-2000
Barry Bisson (Ross Ventures Ltd., Fredericton, NB) 1994-1995
Brenda Bradford (Fisheries and Oceans Canada, Halifax, NS) 1998-2000
Blythe Chang (Fisheries and Oceans Canada, St. Andrews, NB) 1994-2000
Bob Cook (Fisheries and Oceans Canada, Halifax, NS) 1994-1998
Nell Halse (New Brunswick Salmon Growers' Association, St. George, NB) 1999-2000
Russell Henry (New Brunswick Department of Fisheries and Aquaculture, Fredericton, NB) 1994-2000
Murray Hill (Nova Scotia Department of Fisheries, Halifax, NS) 1994-95
Irwin Judson (Nova Scotia Department of Fisheries, Halifax, NS) 1995-96
John Kershaw (New Brunswick Department of Fisheries and Aquaculture, Fredericton, NB) 1994-2000
Linda MacDonald (Atlantic Canada Opportunities Agency, Saint John, NB) 1999-2000
Marli MacNeil (Aquaculture Association of Nova Scotia, Halifax, NS) 1995-2000
Leo Muise (Nova Scotia Department of Fisheries, Halifax, NS) 1997-2000
Fraser Murray (Ross Ventures Ltd., Fredericton, NB) 1995-97
John Pringle (Fisheries and Oceans Canada, Halifax, NS) 1994-1995
Pierre Rioux (New Brunswick Department of Fisheries and Aquaculture, Shippagan, NB) 1998-2000
Bill Thompson (New Brunswick Salmon Growers' Association, St. George, NB) 1994-1999
John van der Meer (National Research Council, Halifax, NS) 1994-2000

**APPENDIX 3**

## STEERING COMMITTEE MEMBERS (1994-2000)

***Observers:***

Iola Price (Fisheries and Oceans Canada, Ottawa, ON)
Tom Sephton (Fisheries and Oceans Canada, Moncton/St. Andrews, NB)
Richard Gallant (Prince Edward Island Department of Fisheries and Tourism,[1] Charlottetown, PE)
Neil McNair (Prince Edward Island Department of Fisheries and Tourism,[1] Charlottetown, PE)
Brian Meaney (Newfoundland and Labrador Department of Fisheries and Aquaculture, St. John's, NF)
Rod Penney (Newfoundland and Labrador Department of Fisheries and Aquaculture, St. John's, NF)

[1] In May 2000, the fisheries and aquaculture components of this department became part of the Prince Edward Island Department of Fisheries, Aquaculture and Environment.

**APPENDIX 4**

## STEERING COMMITTEE MEETINGS

| | |
|---|---|
| 24 October 1994 | St. Andrews (Biological Station) |
| 15 December 1994 | St. Andrews (Biological Station) |
| 26 January 1995 | St. Andrews (Biological Station) |
| 23 February 1995 | Fredericton (Wu Conference Centre) |
| 11 April 1995 | St. Andrews (Biological Station) |
| 08 September 1995 | St. Andrews (Biological Station) |
| 19 October 1995 | Fredericton (Fredericton Motor Inn) |
| 29 November 1995 | St. Andrews (Biological Station) |
| 11 January 1996 | conference call |
| 25 January 1996 | Halifax (Halifax Fisheries Research Laboratory) |
| 28 March 1996 | St. Andrews (Biological Station) |
| 19 June 1996 | St. Andrews (Huntsman Marine Science Centre) |
| 30 October 1996 | Fredericton (Sheraton Inn) |
| 06 February 1997 | St. Andrews (Biological Station) |
| 21 March 1997 | conference call |
| 16 December 1997 | Moncton (Gulf Fisheries Centre) |
| 11 March 1998 | St. Andrews (Biological Station) |
| 16 October 1998 | St. Andrews (Huntsman Marine Science Centre) |
| 25 November 1998 | Fredericton (Fredericton Motor Inn) |
| 18 February 1999 | Moncton (Crystal Palace Hotel) |
| 30 September 1999 | Moncton (Hotel Beauséjour) |
| 08 February 2000 | Moncton (Gulf Fisheries Centre) |

## NEW FINFISH AQUACULTURE SPECIES DEVELOPMENT PROGRAM WORKSHOPS

***22 February 1995***

Hugh John Flemming Complex, Fredericton, NB

- **MacMinn, D. and Watson-Wright, W.** Opening remarks.
- **Benfey, T.** Workplan for eels (UNB).
- **Waiwood, K., Litvak, M., and Lanteigne, C.** Workplans for haddock (DFO Biological Station; HMSC; NBDFA Aquarium and Marine Centre).
- **Waiwood, K.** Workplan for halibut (DFO Biological Station).
- **Litvak, M.** Workplan for winter flounder (HMSC).
- **Peterson, R.** Workplan for striped bass (DFO Biological Station).
- **Madill, H.** Broodstock workplan.
- **Bacon, B.** Fish health workplan.
- **Were, K.** Nutrition workplan.
- **Apold, W.** Engineering workplan.
- Discussion on workplan development and coordination.
- **MacMinn, D. and Watson-Wright, W.** Summary and conclusions.

***17-18 October 1995***

Fredericton Motor Inn, Fredericton, NB

- **Watson-Wright, W.** Opening remarks.
- **Litvak, M.** Development of hatchery techniques for mass production of haddock fry (HMSC, UNBSJ).
- **Waiwood, K.** Refining hatchery techniques for mass production of haddock fry (DFO Biological Station).
- **Lanteigne, C.** Preliminary haddock culture trials (NBDFA Aquarium and Marine Centre).
- **Litvak, M.** Development of hatchery techniques for winter flounder (UNBSJ, HMSC).
- **Peterson, R.** Striped bass and eel culture (DFO Biological Station).
- **Batt, J.** Winter flounder operations (Sambro Fisheries Ltd.).
- **Hammell, L.** Disease investigations and health management (AVC).
- **Griffiths, S. and Olivier, G.** Investigations into possible bacterial influences on larval mortality (RPC, DFO Halifax).
- **Griffiths, S.** Development of rapid diagnostic protocols for diseases (RPC).
- **Olivier, G. (for Morrison, C.).** Study of normal and abnormal development of haddock larvae (DFO Halifax).
- **MacKinnon, B.** Parasite investigations (UNB).
- **Griffiths, S.** Establishment of specific cell lines to permit characterization of viruses (RPC).
- **Were, K. (for Kukal, O.).** Cryopreservation techniques for zooplankton (Atlantic Low Temperature Storage).
- **Castell, J.** Nutritional aspects of larval rearing (DFO Halifax).
- **Madill, H.** Report on broodstock program.
- **Martin-Robichaud, D.** DFO Biological Station broodstock facilities, handling and manipulation.
- **Apold, W.** Update on Engineering Subcommittee.
- **Bernier, M.** Funding of projects, format, approval process, timing, etc.
- Final discussions.

**APPENDIX 5**

## NEW FINFISH AQUACULTURE SPECIES DEVELOPMENT PROGRAM WORKSHOPS

***29-30 October 1996***

Sheraton Inn, Fredericton, NB

- **Watson-Wright, W.** Introduction.
- **Litvak, M.** Results of haddock trials at UNBSJ.
- **Lanteigne, C.** Results of haddock trials at NBDFA Aquarium and Marine Centre.
- **Waiwood, K.** Results of haddock trails at the DFO Biological Station.
- **Waiwood, K. and Raymond, D.** Results of halibut culture trials at the DFO Biological Station/Maritime Mariculture Inc.
- **Casey, P. and Batt, J.** Results of winter flounder trials at HMSC and Sambro Fisheries Ltd.
- **Blair, T. and Castell, J.** Results of live feed analysis.
- **Olivier, G. (for Castell, J.).** Results of live copepod culture trials.
- **Batt. J. and Castell, J.** Feed attractants for winter flounder.
- **Lall, S.** Eel diet development.
- **Hebb, C. and Castell, J.** Nutritional analysis of various protein sources.
- **Gawlicka, A.** Structure of digestive system as it develops (flounders, halibut, haddock).
- **Madill, H.** Report on numbers of fish, eggs produced, and estimated production for 1997 broodstock programs.
- **Griffiths, S.** Report on diagnostics by DFO, RPC, and AVC; major diseases identified and treatments; decreasing bacterial loadings on larvae.
- **Henry, R.** Overview of major constraints to development of the program.
- **MacMinn, D.** Summary and conclusions.

***25-27 November 1998***

Fredericton Motor Inn, Fredericton, NB

- **Henry, R.** Introductory comments.
- **Lanteigne, C.** Overview of haddock culture trials (NBDFA Aquarium and Marine Centre)
- **Johnson, S. and Blanchard, B.** Overview of haddock culture trials and related experiments for 1997 in Sandy Cove (NRC-IMB).
- **Lall, S.** Results of weaning and grower diet development for haddock (NRC-IMB).
- **Frantsi, C.** Results of haddock cage trials: summary of '96 and '97 findings (Connors Bros. Ltd.).
- **Trippel, E.** Results of haddock paired mating and the haddock production run (DFO Biological Station).
- **Castell, J.** Day zero ash values and resulting fertilization/hatching rates for haddock (DFO Biological Station).
- **Wade, J. and Martin-Robichaud, D.** Results of the 1997-98 broodstock research programs and issues involved with egg production (DFO Biological Station).
- **Griffiths, S.** Review of fish health research projects, broodstock screeining and monitoring, and the development of diagnostic techniques (RPC).
- **Raymond, D.** Results of last year's halibut work and identification of existing rearing protocol (Maritime Mariculture Inc.).
- **Raymond, S. and Brown, N.** Results of halibut grower feed trials and a review of operations at Digby (R&R Finfish Development Ltd.).
- **Hogans, W.** Sturgeon project (Supreme Sturgeon and Caviar Ltd./HMSC)
- **Litvak, M.** Sturgeon project (Canadian Caviar Co./UNBSJ)
- Workplan reviews: haddock, halibut, sturgeon.

## NEW FINFISH AQUACULTURE SPECIES DEVELOPMENT PROGRAM WORKSHOPS

***20 October 1999***

Wu Conference Centre, Fredericton, NB

- **Henry, R.** Workshop objectives.
- **Frantsi, C.** Haddock: species update and constraints.
- **Brown, N.** Halibut: species update and constraints.
- **Allen, J.** Small flatfish: species update and constraints.
- **Blanchard, B.** Cod: species update and constraints.
- **Soucy, P. and Hogans, W.** Sturgeon: species update and constraints.
- Development of workplans for each species and discussion.

**APPENDIX 6**

## MAJOR RESEARCH AND DEVELOPMENT PARTNERS

***Government:***

Fisheries and Oceans Canada, St. Andrews Biological Station (St. Andrews, NB)
National Research Council of Canada, Institute for Marine Biosciences (Halifax, NS)
New Brunswick Department of Fisheries and Aquaculture, Aquarium and Marine Centre (Shippagan, NB)
New Brunswick Department of Fisheries and Aquaculture (St. George, NB)

***Universities:***

Atlantic Veterinary College (Charlottetown, PE)
Nova Scotia Agricultural College (Truro, NS)
University of New Brunswick (Fredericton, NB)
University of New Brunswick at Saint John (Saint John, NB)

***Other Research Organizations:***

Huntsman Marine Science Centre (St. Andrews, NB)
Research and Productivity Council (Fredericton, NB)

***Industry Partners and Consultants:***

Canadian Caviar Co. (Saint John, NB)
Connors Bros., Ltd. (Heritage Aquaculture) (Blacks Harbour, NB)
Harbour DeLoutre Products Ltd. (Campobello Island, NB)
Maritime Mariculture Inc. (St. Andrews, NB)
R&R Finfish Development Ltd. (East Ferry, Digby County, NS)
Sambro Fisheries Ltd. (Sambro, NS)
Supreme Sturgeon and Caviar Ltd. (St. George, NB)
Tavel Ltd. (Dartmouth, NS)

# PROJECTS FUNDED BY THE CANADA–NEW BRUNSWICK–NOVA SCOTIA NEW FINFISH AQUACULTURE SPECIES DEVELOPMENT PROGRAM

Projects were funded on a fiscal year basis, from 1 April to 31 March of the following calendar year.
Abbreviations are listed at the end of this Appendix.

## 1994-95

Note: the program was not fully operational in 1994-95. Two projects were partially funded late in the fiscal year (in early 1995).

***Nutrition***

| | |
|---|---|
| *Title:* | **Preliminary haddock feeding trials at the Aquarium and Marine Centre (Shippagan)** |
| *Project Leader(s):* | NBDFA Shippagan (C. Lanteigne); DFO Halifax (J. Castell) |
| *Species:* | haddock |
| *Description:* | Review literature on marine fish nutrition and lipid metabolism. Determine lipid and fatty acid composition of live feeds and haddock larvae. |

***Fish Health***

| | |
|---|---|
| *Title:* | **Establishment of specific cell lines to permit characterization of viruses** |
| *Project Leader(s):* | Research & Productivity Council (S. Griffiths) |
| *Species:* | haddock, halibut |
| *Description:* | In anticipation of viral diseases impacting on new finfish species, this prepares the way for diagnosing viruses by first establishing the host cell line cultures which are a prerequisite to viral analyses. |

## 1995-96

***Broodstock***

| | |
|---|---|
| *Title:* | **Broodstock holding and management** |
| *Project Leader(s):* | NBDFA St. George (H. Madill); DFO St. Andrews; NBDFA Shippagan; HMSC; Harbour de Loutre Products; F. Trask (Little River, Digby County, NS) |
| *Species:* | haddock, halibut, winter flounder, striped bass |
| *Description:* | Maintain broodstock at various sites, as required by the Program. |
| *Title:* | **Broodstock collection** |
| *Project Leader(s):* | NBDFA St. George (H. Madill); DFO St. Andrews |
| *Species:* | haddock, halibut |
| *Description:* | Collect and/or purchase broodstock, as required by the Program. |
| *Title:* | **Infrastructure development for Biological Station broodstock holding facility** |
| *Project Leader(s):* | DFO St. Andrews (D. Martin-Robichaud) |
| *Species:* | haddock, halibut |
| *Description:* | Produce a fully functional, multispecies broodstock research and development facility at the Biological Station, by equipping the unfinished facility with necessary electrical and plumbing equipment. |

***Early Rearing***

| | |
|---|---|
| *Title:* | **Refining hatchery techniques for mass production of haddock fry at DFO St. Andrews** |
| *Project Leader(s):* | DFO St. Andrews (K. Waiwood) |
| *Species:* | haddock |
| *Description:* | Evaluate systems for promoting a beneficial microbial environment for yolk sac and early feeding haddock larvae, to determine the benefit, if any, of green water, and to compare performance using different culture systems and feeding strategies. |
| *Title:* | **Development of hatchery techniques for haddock aquaculture at HMSC** |
| *Project Leader(s):* | HMSC/UNBSJ (M. Litvak) |
| *Species:* | haddock |
| *Description:* | Develop new hatchery technology and techniques for haddock culture. Determine environmental factors that promote rapid growth and survival of larvae, including tank type, water quality, light regime, food, and stocking density. Haddock light research. |
| *Title:* | **Development of hatchery techniques for winter flounder aquaculture at HMSC** |
| *Project Leader(s):* | HMSC/UNBSJ (M. Litvak) |
| *Species:* | winter flounder |
| *Description:* | Develop new hatchery technology and techniques for winter flounder culture. Determine environmental factors that promote rapid growth and survival of larvae, including tank type, water quality, light regime, food, and stocking density. |

## APPENDIX 7

# PROJECTS FUNDED BY THE CANADA–NEW BRUNSWICK–NOVA SCOTIA NEW FINFISH AQUACULTURE SPECIES DEVELOPMENT PROGRAM

**1995-96 (continued)**

***Early Rearing (continued)***

| | |
|---|---|
| *Title:* | **Striped bass swimbladder inflation research** |
| *Project Leader(s):* | DFO St. Andrews (R. Peterson) |
| *Species:* | striped bass |
| *Description:* | Study the influence of light intensity and tank color on swimbladder inflation success of larval striped bass. Preparation and publication of a striped bass culture manual. |
| *Title:* | **Eel culture research** |
| *Project Leader(s):* | DFO St. Andrews (R. Peterson); UNB (T. Benfey) |
| *Species:* | American eel |
| *Description:* | Experiments on environmental factors determining sex in cultured eels, including temperature manipulation, stocking density, and feeding rations. |

***Nutrition***

| | |
|---|---|
| *Title:* | **Haddock feeding trials at the Aquarium and Marine Centre (Shippagan)** |
| *Project Leader(s):* | NBDFA Shippagan (C. Lanteigne); DFO Halifax (J. Castell) |
| *Species:* | Haddock |
| *Description:* | Conduct feeding trials with haddock larvae using four diets and several tank designs. |
| *Title:* | **Analysis of live food organisms and larval marine fish** |
| *Project Leader(s):* | DFO Halifax (J. Castell) |
| *Species:* | various |
| *Description:* | Analyze the nutritional composition of algae, enrichment media, live food organisms, and cultured fish larvae at each laboratory involved in larval marine fish culture. |
| *Title:* | **Nutritional studies on the utilization of various protein sources during the growout stages of marine fish** |
| *Project Leader(s):* | DFO Halifax (J. Castell); Sambro Fisheries Ltd. (J. Batt); NSAC (D. Anderson) |
| *Species:* | various |
| *Description:* | Prepare a reference diet based upon the limited published information on nutritional requirements of marine flatfish species. This reference diet, as well as several commercial feeds, will be fed to juvenile winter flounders. Comparisons will include survival, growth, feed efficiency, net protein utilization, total dry matter, and protein digestibility. |
| *Title:* | **Diet development for eels** |
| *Project Leader(s):* | DFO Halifax (S. Lall); NSAC (D. Anderson) |
| *Species:* | American eel |
| *Description:* | Find suitable feed attractants for eels, which will improve feed acceptance, reduce mortality, and improve growth of wild eels captured for aquaculture. |
| *Title:* | **Cryopreservation research** |
| *Project Leader(s):* | Atlantic Low Temperature Storage (O. Kukal) |
| *Species:* | various |
| *Description:* | Achieve long-term cryopreservation of bivalve larvae using an efficient and cost-effective system. Initial trials will target trochophores and veligers of scallops. |

***Fish Health***

| | |
|---|---|
| *Title:* | **Disease investigations & health management for new finfish species** |
| *Project Leader(s):* | NBDFA St. George (J. O'Halloran); Atlantic Veterinary College (L. Hammell) |
| *Species:* | various |
| *Description:* | Investigation of disease outbreaks through emergency site visits, diagnostic testing, and reporting; routine health and production monitoring; development of histopathological diagnostic protocols for haddock and halibut. |
| *Title:* | **Investigation into possible bacterial influences on larval mortality** |
| *Project Leader(s):* | Research & Productivity Council (S. Griffiths); DFO Halifax; NBDFA; Atlantic Veterinary College |
| *Species:* | haddock, flounder |
| *Description:* | Determine the influence of bacterial activity in haddock and halibut rearing facilities on larval survival and growth. |

# PROJECTS FUNDED BY THE CANADA–NEW BRUNSWICK–NOVA SCOTIA NEW FINFISH AQUACULTURE SPECIES DEVELOPMENT PROGRAM

**1995-96 (continued)**

***Fish Health (continued)***

| | |
|---|---|
| *Title:* | **Development of rapid diagnostic protocol for diseases** |
| *Project Leader(s):* | Research & Productivity Council (S. Griffiths, J. Lovely) |
| *Species:* | various |
| *Description:* | Develop rapid DNA diagnostic test for new bacteria or viruses not yet encountered and for which no DNA primers sequences have been published. The model system can then be utilized as the basis for subsequently quickly identifying newly encountered pathogens. |
| *Title:* | **Study of normal and abnormal development of cultured haddock larvae** |
| *Project Leader(s):* | DFO Halifax (C. Morrison) |
| *Species:* | haddock |
| *Description:* | Preparation of an aquaculturist's atlas of normal and abnormal haddock larvae. |
| *Title:* | **Establishment of specific cell lines to permit characterization of viruses** |
| *Project Leader(s):* | Research & Productivity Council (S. Griffiths) |
| *Species:* | haddock, halibut |
| *Description:* | In anticipation of viral diseases impacting on new finfish species, this prepares the way for diagnosing viruses by first establishing the host cell line cultures which are a prerequisite to viral analyses. |
| *Title:* | **Investigation into impact of parasites on commercial. of winter flounder** |
| *Project Leader(s):* | UNB (B. MacKinnon) |
| *Species:* | winter flounder |
| *Description:* | Investigate the potential threat that the larval digenean flatworm *Stephanostomum buccatum* poses in the commercialization of winter flounder, including: prevalence of infection in wild-caught young and older flounders; extent of invasion into fish musculature; progression of infection in fish held in tanks post-capture; and attempt to ascertain the snail host species. |

***Engineering and Technology***

| | |
|---|---|
| *Title:* | **Engineering review of aquaculture facilities** |
| *Project Leader(s):* | various |
| *Species:* | various |
| *Description:* | Identification of specific infrastructure and instrumentation needs at research facilities, to allow them to undertake the planned research. |
| *Title:* | **Development of bioeconomic decision model** |
| *Project Leader(s):* | Tavel Ltd. (W. Apold) |
| *Species:* | winter flounder |
| *Description:* | Develop production/economic models, research target adjustments, and time lines for winter flounder aquaculture. |

**APPENDIX 7**

# PROJECTS FUNDED BY THE CANADA–NEW BRUNSWICK–NOVA SCOTIA NEW FINFISH AQUACULTURE SPECIES DEVELOPMENT PROGRAM

**1996-97**

| | |
|---|---|
| ***Broodstock*** | |
| *Title:* | **Broodstock holding and management** |
| *Project Leader(s):* | NBDFA St. George (H. Madill); DFO St. Andrews; NBDFA Shippagan; HMSC; Harbour de Loutre Products; F. Trask (Little River, Digby County, NS); Sambro Fisheries Ltd. |
| *Species:* | haddock, halibut, winter flounder, striped bass |
| *Description:* | Maintain broodstock at various sites, as required by the Program. |
| *Title:* | **Broodstock collection** |
| *Project Leader(s):* | NBDFA St. George (H. Madill); DFO St. Andrews |
| *Species:* | haddock, halibut |
| *Description:* | Collect and/or purchase broodstock, as required by the Program. |
| ***Early Rearing*** | |
| *Title:* | **Halibut seedstock production facility - Maritime Mariculture Inc.** |
| *Project Leader(s):* | Maritime Mariculture Inc. (D. Raymond) |
| *Species:* | halibut |
| *Description* | Develop technology for mass production of juvenile halibut in Atlantic Canada. Determine optimal growth and survival conditions for juvenile halibut. |
| *Title:* | **Haddock project at the Aquarium and Marine Centre (Shippagan)** |
| *Project Leader(s):* | NBDFA Shippagan (C. Lanteigne) |
| *Species:* | haddock |
| *Description:* | Conduct trials to determine appropriate culture techniques for haddock juvenile production, including: incubation technology, contamination of larval tanks, new tank design, impact of transfers at various times on survival. |
| *Title:* | **Early rearing workplan for haddock at UNBSJ** |
| *Project Leader(s):* | UNBSJ (M. Litvak) |
| *Species:* | haddock |
| *Description:* | Determine appropriate light intensity, spectrum and tank color; parameters for larval tank design; larval feeding regimes; stocking and feeding densities. |
| *Title:* | **Early rearing workplan for winter flounder at HMSC** |
| *Project Leader(s):* | HMSC/UNBSJ (M. Litvak) |
| *Species:* | winter flounder |
| *Description:* | Determine the appropriate rearing environment, both physical and biological, that will promote high survival and growth of winter flounder under culture conditions. |
| ***Nutrition*** | |
| *Title:* | **Live feeds analysis** |
| *Project Leader(s):* | DFO Halifax (J. Castell) |
| *Species:* | various |
| *Description:* | Monitor the composition of live food organisms fed to marine fish larvae, so that correlations between composition and larval growth and survival can be evaluated |
| *Title:* | **Live copepod culture trials** |
| *Project Leader(s):* | DFO Halifax (J. Castell); Sambro Fisheries Ltd. (J. Batt); Dalhousie U. (D. Nanton) |
| *Species:* | various |
| *Description:* | Evaluate alternative mass culture systems for harpacticoid copepods to permit larval marine fish feeding trials to be conducted. |
| *Title:* | **Nutritional studies on the utilization of various protein sources during the growout stages of marine fish** |
| *Project Leader(s):* | DFO Halifax (J. Castell); Sambro Fisheries Ltd. (J. Batt); NSAC (D. Anderson) |
| *Species:* | various |
| *Description:* | Investigate options and alternatives in sources and levels of protein and amino acids required by marine fish with aquaculture potential. |
| *Title:* | **Diet development for eels** |
| *Project Leader(s):* | DFO Halifax (S. Lall); NSAC (D. Anderson) |
| *Species:* | American eel |
| *Description:* | Evaluate the effectiveness of natural feed ingredients and synthetic compounds in enhancing the palatability and feed acceptance of eel diets. |

# PROJECTS FUNDED BY THE CANADA–NEW BRUNSWICK–NOVA SCOTIA NEW FINFISH AQUACULTURE SPECIES DEVELOPMENT PROGRAM

**1996-97 (continued)**

| ***Nutrition (continued)*** | |
|---|---|
| *Title:* | **Feed attractants for winter flounder** |
| *Project Leader(s):* | Sambro Fisheries Ltd. (J. Batt); DFO Halifax (J. Castell) |
| *Species:* | winter flounder |
| *Description:* | Test the effect of using different taste stimulators to increase food consumption of winter flounder. |

| ***Fish Health*** | |
|---|---|
| *Title:* | **Fish health diagnostic services** |
| *Project Leader(s):* | DFO Halifax (C. Morrison); Research & Productivity Council (S. Griffiths); Atlantic Veterinary College (D. Groman) |
| *Species:* | various |
| *Description:* | Conduct diagnostic studies on eggs and larvae produced within the New Finfish Aquaculture Species Program. |
| *Title:* | **Decreasing bacterial load associated with feed/prey items for larvae** |
| *Project Leader(s):* | Research & Productivity Council (S. Griffiths) |
| *Species:* | various |
| *Description:* | Assess antibiotic and probiotic treatment in rotifer cultures. Assess efficacy of food treatment on larval viability. |

| ***Engineering and Technology*** | |
|---|---|
| *Title:* | **Short term consulting assistance** |
| *Project Leader(s):* | various |
| *Species:* | various |
| *Description:* | Provide technical advice regarding systems design for broodstock and research facilities within the Program. |
| *Title:* | **Development of bioeconomic decision models** |
| *Project Leader(s):* | Tavel Ltd. (W. Apold) |
| *Species:* | all priority species |
| *Description:* | Develop bioeconomic decision models to identify key constraints to commercialization for marine finfish species with aquaculture potential. |

## APPENDIX 7

# PROJECTS FUNDED BY THE CANADA–NEW BRUNSWICK–NOVA SCOTIA NEW FINFISH AQUACULTURE SPECIES DEVELOPMENT PROGRAM

**1997-98**

***Broodstock***

| | |
|---|---|
| *Title:* | **Broodstock holding and management** |
| *Project Leader(s):* | NBDFA St. George (H. Madill); DFO St. Andrews; NBDFA Shippagan; HMSC; Harbour de Loutre Products; F. Trask (Little River, Digby County, NS); Sambro Fisheries Ltd.; R&R |
| *Species:* | haddock, halibut, winter flounder, striped bass |
| *Description:* | Maintain broodstock at various sites, as required by the Program. |
| *Title:* | **Broodstock collection** |
| *Project Leader(s):* | NBDFA St. George (H. Madill); DFO St. Andrews |
| *Species:* | haddock, halibut |
| *Description:* | Collect and/or purchase broodstock, as required by the Program. |
| *Title:* | **Investigation of aspects of reproductive physiology of haddock and halibut** |
| *Project Leader(s):* | DFO St. Andrews (D. Martin-Robichaud) |
| *Species:* | haddock, halibut |
| *Description:* | Conduct studies on various aspects of haddock and halibut reproductive physiology, pertaining to broodstock development. |

***Early Rearing***

| | |
|---|---|
| *Title:* | **Collection and transfer of halibut eggs and set-up incubation system** |
| *Project Leader(s):* | R&R (S. Raymond, N. Brown) |
| *Species:* | halibut |
| *Description:* | Production of eggs at DFO St. Andrews; transfer to HMSC to rear to 150+ degree days, to allow start of production at R&R in 1997. |
| *Title:* | **Halibut seedstock production facility - Maritime Mariculture Inc.** |
| *Project Leader(s):* | Maritime Mariculture Inc. (D. Raymond) |
| *Species:* | halibut |
| *Description:* | Building on success in 1996/97, facilities will be upgraded to minimize water flow disruptions; ensure temperature controls are adequate and water clarity and quality are optimal. |
| *Title:* | **Haddock project at the Aquarium and Marine Centre (Shippagan)** |
| *Project Leader(s):* | NBDFA Shippagan (C. Lanteigne) |
| *Species:* | haddock |
| *Description:* | Adapt and refine existing technology to develop larval rearing and live feed culture techniques for pilot scale production of haddock juveniles. |
| *Title:* | **Early rearing workplan for haddock at UNBSJ** |
| *Project Leader(s):* | UNBSJ (M. Litvak, G. Downing) |
| *Species:* | haddock |
| *Description:* | Determine appropriate light intensity, spectral intensity, and photoperiodicity for egg incubation and for larvae. |
| *Title:* | **Early rearing workplan for winter flounder at Sambro Fisheries Ltd.** |
| *Project Leader(s):* | Sambro Fisheries Ltd. (J. Batt) |
| *Species:* | winter flounder |
| *Description:* | Determine the appropriate rearing environment, both physical and biological, that will promote high survival and growth of winter flounder under culture conditions. Develop protocol for declumping eggs after fertilization. |

***Growout***

| | |
|---|---|
| *Title:* | **Juvenile halibut growout - R&R Finfish Development Ltd.** |
| *Project Leader(s):* | R&R (S. Raymond, N. Brown) |
| *Species:* | halibut |
| *Description:* | Nursery and growout nutrition; intensive culture system development. |
| *Title:* | **Juvenile haddock production project** |
| *Project Leader(s):* | Connors Bros. Ltd. (C. Frantsi); NBDFA Shippagan (C. Lanteigne); HMSC (J. Allen) |
| *Species:* | haddock |
| *Description:* | Pilot scale hatchery, nursery, and ongrowing study. Develop nursery protocols for juvenile production. Evaluate ongrowing in existing salmon sea cages. |

# PROJECTS FUNDED BY THE CANADA–NEW BRUNSWICK–NOVA SCOTIA NEW FINFISH AQUACULTURE SPECIES DEVELOPMENT PROGRAM

**1997-1998 (continued)**

| | |
|---|---|
| ***Growout (continued)*** | |
| *Title:* | **Determination of temperature tolerance of haddock and other aquaculture species** |
| *Project Leader(s):* | Connors Bros. Ltd. (C. Graham, C. Frantsi); NRC-IMB (V. Ewart) |
| *Species:* | haddock, others |
| *Description:* | Determine temperature tolerance of haddock and other candidate marine finfish species; test for antifreeze proteins in vitro. |
| ***Nutrition*** | |
| *Title:* | **Analysis of live food organisms and marine fish** |
| *Project Leader(s):* | DFO Halifax/St. Andrews (J. Castell) |
| *Species:* | various |
| *Description:* | Monitor the composition of live food organisms fed to marine fish larvae, so that correlations between composition and larval growth and survival can be evaluated |
| *Title:* | **Nutritional studies on the utilization of various protein sources during the growout stages of marine fish** |
| *Project Leader(s):* | DFO Halifax/St. Andrews (J. Castell); Sambro Fisheries Ltd. (J. Batt); NSAC (D. Anderson, C. Hebb) |
| *Species:* | winter flounder, various |
| *Description:* | Investigate options and alternatives in sources and levels of protein and amino acids required by marine fish with aquaculture potential. |
| *Title:* | **Diet development for eels** |
| *Project Leader(s):* | NRC-IMB (S. Lall); NSAC (D. Anderson, S. Tibbetts) |
| *Species:* | American eel |
| *Description:* | Evaluate the effectiveness of natural feed ingredients and synthetic compounds in enhancing the palatability and feed acceptance of eel diets. |
| *Title:* | **Development of high performance weaning diet for winter flounder** |
| *Project Leader(s):* | Sambro Fisheries Ltd. (J. Batt); DFO Halifax/St. Andrews (J. Castell) |
| *Species:* | winter flounder |
| *Description:* | Diet formulation for increased growth and survival of winter flounder during the crucial weaning period. |
| *Title:* | **Functional development of stomach of winter flounder** |
| *Project Leader(s):* | NRC-IMB (S. Douglas, A. Gawlicka) |
| *Species:* | winter flounder |
| *Description:* | Describe the functional ontogeny of the stomach from hatching to metamorphosis. Will attempt to localize and determine the onset of pepsin expression. Comparisons will be made with larvae of other species such as yellowtail flounder, halibut, and haddock. |
| *Title:* | **Striped bass research** |
| *Project Leader(s):* | NSAC (J. Duston) |
| *Species:* | striped bass |
| *Description:* | Research on nutritional requirements of striped bass larvae, including use of enriched *Artemia*. Effects of water velocity on growth and food conversion of juvenile striped bass. |
| ***Fish Health*** | |
| *Title:* | **Comprehensive surveillance and characterization of larval virology and bacteriology** |
| *Project Leader(s):* | Research & Productivity Council (B. Bacon); NBDFA Shippagan; UNBSJ; DFO St. Andrews |
| *Species:* | various |
| *Description:* | Improved surveillance will be achieved by ensuring collection and processing of samples from all moribund larvae. A comprehensive report of the results will be produced. |
| *Title:* | **Surveillance of broodstock virology and bacteriology** |
| *Project Leader(s):* | Research & Productivity Council (B. Bacon); NBDFA Shippagan; UNBSJ; DFO St. Andrews |
| *Species:* | various |
| *Description:* | Close surveillance of broodstock and reproductive fluids for potentially breaking infections and vertically transmitted diseases. |

**APPENDIX 7**

# PROJECTS FUNDED BY THE CANADA–NEW BRUNSWICK–NOVA SCOTIA NEW FINFISH AQUACULTURE SPECIES DEVELOPMENT PROGRAM

**1997-98 (continued)**

***Fish Health (continued)***

| | |
|---|---|
| *Title:* | **Larval production system monitoring for bacterial load** |
| *Project Leader(s):* | Research & Productivity Council (S. Griffiths); NBDFA Shippagan; UNBSJ; DFO St. Andrews |
| *Species:* | various |
| *Description:* | Polymerase Chain Reaction (PCR) tests for *Vibrio* and *Aeromonas* will be multiplexed with an assay for bacterial load. |
| *Title:* | **Analytical services** |
| *Project Leader(s):* | Atlantic Veterinary College (D. Groman) |
| *Species:* | various |
| *Description:* | Analysis of samples submitted by rearing facilities. The results are submitted to the client rearing facility and NBDFA for review by a veterinarian. |
| *Title:* | **Veterinary services** |
| *Project Leader(s):* | NBDFA St. George |
| *Species:* | various |
| *Description:* | The results submitted by analytical and research laboratories require review by a veterinarian to ensure that the appropriate clinical interpretation is provided and that any subsequent treatment or other action is undertaken. |

***Engineering and Technology***

| | |
|---|---|
| *Title:* | **Short term consulting assistance** |
| *Project Leader(s):* | various |
| *Species:* | various |
| *Description:* | Provision of technical assistance for design and trouble-shooting of experimental system designs prior to construction and experimental initiation. |

**APPENDIX 7**

# PROJECTS FUNDED BY THE CANADA–NEW BRUNSWICK–NOVA SCOTIA NEW FINFISH AQUACULTURE SPECIES DEVELOPMENT PROGRAM

**1998-99**

| | |
|---|---|
| ***Broodstock*** | |
| *Title:* | **Broodstock holding and management** |
| *Project Leader(s):* | NBDFA St. George (H. Madill), DFO St. Andrews; NBDFA Shippagan; HMSC; Harbour de Loutre Products; F. Trask (Little River, Digby County, NS); Sambro Fisheries Ltd.; R&R; Connors Bros. |
| *Species:* | haddock, halibut, winter flounder, striped bass |
| *Description:* | Maintain broodstock at various sites, as required by the Program. |
| *Title:* | **Broodstock collection** |
| *Project Leader(s):* | NBDFA St. George (H. Madill); DFO St. Andrews |
| *Species:* | haddock, halibut |
| *Description:* | Collect and/or purchase broodstock, as required by the Program. |
| *Title:* | **Reproductive physiology of haddock and halibut** |
| *Project Leader(s):* | DFO St. Andrews (D. Martin-Robichaud) |
| *Species:* | haddock, halibut |
| *Description:* | Conduct studies on various aspects of haddock and halibut reproductive physiology, pertaining to broodstock development. |
| ***Early Rearing*** | |
| *Title:* | **Halibut seedstock production facility - Maritime Mariculture Inc.** |
| *Project Leader(s):* | Maritime Mariculture Inc. (D. Raymond), HMSC |
| *Species:* | halibut |
| *Description:* | Production of 15,000-20,000 juvenile halibut; related research. |
| *Title:* | **Haddock project at the Aquarium and Marine Centre (Shippagan)** |
| *Project Leader(s):* | NBDFA Shippagan (C. Lanteigne) |
| *Species:* | haddock |
| *Description:* | Continue to adapt and refine rearing technology for commercial production; determine weaning success of haddock; and perform nursery trials in tanks. Production objective is 25,000 juveniles. |
| *Title:* | **Haddock light research** |
| *Project Leader(s):* | UNBSJ (M. Litvak, G. Downing) |
| *Species:* | haddock |
| *Description:* | Determine best photic environment (photoperiod, light intensity, spectral composition) in which to raise early life history stages of haddock. |
| ***Nutrition*** | |
| *Title:* | **Juvenile halibut feeding trials in tanks** |
| *Project Leader(s):* | DFO St. Andrews (J. Castell); Maritime Mariculture Inc. |
| *Species:* | halibut |
| *Description:* | Conduct tank trials on 5-10 g juvenile halibut, comparing 4 diets. |
| *Title:* | **Development and evaluation of a weaning diet for haddock** |
| *Project Leader(s):* | NRC-IMB (S. Lall) |
| *Species:* | haddock |
| *Description:* | Examine the nutritional quality of commercial larval feeds and develop an experimental weaning diet for haddock. |
| *Title:* | **Striped bass research** |
| *Project Leader(s):* | NSAC (J. Duston) |
| *Species:* | striped bass |
| *Description:* | Research on the effects of prey density on feeding rates of larval striped bass. Determination of gut evacuation rate of larval striped bass. |
| ***Fish Health*** | |
| *Title:* | **Fish health services** |
| *Project Leader(s):* | Research & Productivity Council (B. Bacon) |
| *Species:* | various |
| *Description:* | Provision of various fish health services for the New Finfish Aquaculture Species Development Program. |

# PROJECTS FUNDED BY THE CANADA–NEW BRUNSWICK–NOVA SCOTIA NEW FINFISH AQUACULTURE SPECIES DEVELOPMENT PROGRAM

**1999-2000**

| | |
|---|---|
| ***Broodstock*** | |
| *Title:* | **Broodstock holding and management** |
| *Project Leader(s):* | NBDFA St. George (H. Madill); DFO St. Andrews; NBDFA Shippagan; HMSC; Harbour de Loutre Products; F. Trask (Little River, Digby County, NS); Sambro Fisheries Ltd.; R&R; Connors Bros. |
| *Species:* | haddock, halibut, winter flounder, striped bass |
| *Description:* | Maintain broodstock at various sites, as required by the Program. |
| *Title:* | **Broodstock collection** |
| *Project Leader(s):* | NBDFA St. George (H. Madill); DFO St. Andrews |
| *Species:* | haddock, halibut |
| *Description:* | Collect and/or purchase broodstock, as required by the Program. |
| *Title:* | **Haddock egg incubation and distribution** |
| *Project Leader(s):* | DFO St. Andrews (D. Martin-Robichaud) |
| *Species:* | Haddock |
| *Description:* | Set up and operate an egg incubation system to hold haddock eggs 7-10 days to minimize transport mortality during early sensitive developmental stages. |
| *Title:* | **Assessment of juvenile halibut production using microsatellite markers** |
| *Project Leader(s):* | NRC-IMB (M. Reith) |
| *Species:* | halibut |
| *Description:* | Use of microsatellite markers to determine the parentage of halibut juveniles reared under aquaculture conditions in Atlantic Canada. |
| ***Early Rearing*** | |
| *Title:* | **Maritime Mariculture Inc. halibut seedstock production facility** |
| *Project Leader(s):* | Maritime Mariculture Inc. (D. Raymond), HMSC |
| *Species:* | halibut |
| *Description:* | Conduct semi-commercial scale production trials at HMSC, with production target of 50,000 juveniles. |
| *Title:* | **R&R Finfish Development Ltd. halibut production facility** |
| *Project Leader(s):* | R&R (S. Raymond, N. Brown) |
| *Species:* | halibut |
| *Description:* | Reduction of bacterial loading on *Artemia* by disinfection and feeding trials with halibut using disinfected *Artemia*; the effect of tank depth on halibut growth; broodstock development and maintenance. |
| *Title:* | **Haddock project at Aquarium et Centre Marin (Shippagan)** |
| *Project Leader(s):* | NBDFA Shippagan (C. Lanteigne) |
| *Species:* | Haddock |
| *Description:* | Production of 25,000 juvenile haddock (5 g), mainly for Connors Bros. growout trials. |
| *Title:* | **Haddock juvenile production and experimental weaning** |
| *Project Leader(s):* | DFO St. Andrews (E. Trippel) |
| *Species:* | Haddock |
| *Description:* | Juvenile haddock project including both production and research components. Eggs will be produced from paired matings. Larvae will be fed on algae and zooplankton, with subsequent weaning to dry food. |
| *Title:* | **Development of commercial haddock culture** |
| *Project Leader(s):* | Connors Bros. Ltd. (C. Frantsi), NRC-IMB (S. Johnson); NBDFA Shippagan (C. Lanteigne) |
| *Species:* | Haddock |
| *Description:* | Conduct research to refine haddock hatchery techniques; prepare cost and design models; prepare hatchery manual. |
| *Title:* | **Develop technology and protocols to cultivate small flatfish at HMSC** |
| *Project Leader(s):* | HMSC (J. Allen) |
| *Species:* | small flounders |
| *Description:* | Develop and refine the culture requirements of various small flatfish species for ongrowing projects in the Bay of Fundy. |
| ***Growout*** | |
| *Title:* | **Halibut growout trials** |
| *Project Leader(s):* | Harbour DeLoutre Products Ltd. (J. Malloch); Maritime Mariculture Inc. (D. Raymond) |
| *Species:* | Halibut |
| *Description:* | Growout 8,000 juvenile halibut from Maritime Mariculture Inc. 1998 year-class in sea cages. |

# PROJECTS FUNDED BY THE CANADA–NEW BRUNSWICK–NOVA SCOTIA NEW FINFISH AQUACULTURE SPECIES DEVELOPMENT PROGRAM

**1999-2000 (continued)**

| *Growout (continued)* | |
|---|---|
| *Title:* | **Haddock growout trials** |
| *Project Leader(s):* | Connors Bros. Ltd. (C. Frantsi); NRC-IMB (S. Johnson); NBDFA Shippagan (C. Lanteigne) |
| *Species:* | haddock |
| *Description:* | Conduct cage trials with 3 year-classes to determine the potential for commercial production. |
| *Title:* | **Sturgeon aquaculture - Supreme Sturgeon and Caviar Ltd.** |
| *Project Leader(s):* | Supreme Sturgeon and Caviar (B. Tucker); HMSC (W. Hogans) |
| *Species:* | Shortnose sturgeon |
| *Description:* | Research on various constraints to sturgeon aquaculture. |
| *Title:* | **Sturgeon aquaculture - Canadian Caviar Co.** |
| *Project Leader(s):* | Canadian Caviar Co. (P. Soucy); UNBSJ (M. Litvak) |
| *Species:* | Shortnose and Atlantic sturgeon |
| *Description:* | Research on various constraints to sturgeon aquaculture. |

| *Nutrition* | |
|---|---|
| *Title:* | **Diet development for haddock culture** |
| *Project Leader(s):* | NRC-IMB (S. Lall) |
| *Species:* | haddock |
| *Description:* | Research on factors affecting fatty liver condition in juvenile haddock; development of least cost feed formulations; development of practical feeding strategies for haddock rearing. |
| *Title:* | **Larval haddock and halibut feeding trials with cultured copepods** |
| *Project Leader(s):* | DFO St. Andrews (J. Castell) |
| *Species:* | haddock, halibut |
| *Description:* | Experiments to culture a copepod as live feed for haddock and halibut larvae. |
| *Title:* | **Lipid absorption, survival, and growth in winter flounder and haddock** |
| *Project Leader(s):* | Sambro Fisheries Ltd. (J. Batt); DFO St. Andrews (J. Castell) |
| *Species:* | winter flounder, haddock |
| *Description:* | Determine the effect of Highly Unsaturated Fatty Acid (HUFA) absorption on larval success in winter flounder and haddock larvae. |
| *Title:* | **Striped bass research** |
| *Project Leader(s):* | NSAC (J. Duston) |
| *Species:* | striped bass |
| *Description:* | Research on the effect of light intensity on the feeding rate of larval striped bass. Research on the effect of ration on growth of juvenile striped bass. |

| *Fish Health* | |
|---|---|
| *Title:* | **Characterization of bacteria and viruses implicated in culture problems** |
| *Project Leader(s):* | Research & Productivity Council (S. Griffiths) |
| *Species:* | haddock, halibut, sturgeon |
| *Description:* | Characterization of bacteria and viruses implicated in culture problems at haddock, halibut, and sturgeon rearing facilities. |
| *Title:* | **Live feed quality and treatment assessment** |
| *Project Leader(s):* | Research & Productivity Council (S. Griffiths) |
| *Species:* | haddock, halibut |
| *Description:* | Assessment of live feed for potential contaminants, prior to use in production trials. |

**ABBREVIATIONS:**

| | |
|---|---|
| DFO | Fisheries and Oceans Canada |
| HMSC | Huntsman Marine Science Centre (St. Andrews, NB) |
| NBDFA | New Brunswick Department of Fisheries and Aquaculture |
| NSAC | Nova Scotia Agricultural College (Truro, NS) |
| NRC-IMB | National Research Council of Canada, Institute for Marine Biosciences (Halifax, NS) |
| R&R | R&R Finfish Development Ltd. (East Ferry, Digby County, NS) |
| UNB | University of New Brunswick (Fredericton, NB) |
| UNBSJ | University of New Brunswick at Saint John (Saint John, NB) |